Guidelines for Natural Hazard Risk Analysis on Public Conservation Lands and Waters

Part 1: Risk-Analysis Framework

SJ de Vilder
DR Burbidge
CI Massey
NI Deligne
WL Power
GS Leonard

GNS Science Consultancy Report 2024/35
September 2024 – Revised August 2025

DISCLAIMER

Use of Data:

Date that GNS Science can use associated data: June 2020

BIBLIOGRAPHIC REFERENCE

de Vilder SJ, Massey CI, Power WL, Burbidge DR, Deligne NI, Leonard GS. 2024. Guidelines for natural hazard risk analysis on public conservation lands and waters – Part 1: risk-analysis framework. Lower Hutt (NZ): GNS Science. 26 p. Consultancy Report 2024/35. Revised August 2025.

CONTENTS

FIGURES

TABLES

EXECUTIVE SUMMARY

This report presents a natural hazard risk-analysis framework for landslide, tsunami and volcanic hazards that can potentially impact sites on public conservation lands and waters (Department-of-Conservation-managed land) such as huts, tracks and roads. The natural hazard risk-analysis framework is concerned with life-safety considerations and life-safety risk to both visitors and workers on public conservation lands and waters, as well as impacts to huts and other similar significant infrastructure and assets.

There is increasing need to undertake risk analysis on public conservation lands and waters, due to increasing visitor numbers, and to understand natural hazard risks to visitor sites. This requires a consistent and standardised risk methodology across the various visitor sites on public conservation lands and waters. The risk analysis is required to be undertaken in order to: (1) identify and define 'high risk' areas, (2) help the Department of Conservation (DOC) manage the risk to visitors at 'high risk' locations and (3) inform visitors of the levels of risk they may be exposing themselves to from natural hazards when accessing these sites. Additionally for landslide hazards, the methodology assesses whether a hut or other similar significant infrastructure or asset can be impacted by a landslide hazard and, if so, what the potential mitigation options may be. The purpose of the natural hazard risk-analysis framework is to enable informed and consistent risk-management decisions across public conservation lands and waters. The report provides technical guidance on the use of the framework for identifying and prioritising risk-management actions for each natural hazard. The framework consists of three levels:

1. Preliminary screening.
2. Basic analysis and/or risk mitigation.
3. Advanced analysis and/or risk mitigation.

It is intended that the hazards at a site are initially analysed using the Part 2, 5 and 6 preliminary screening methodology reports, which contain the preliminary screening methodology for each natural hazard. The purpose of the preliminary screening methodology is to determine whether more analysis and/or risk mitigation (either basic or advanced level) is needed at a site and to assist in assigning priority to such analyses. Due to the different characteristics of the natural hazards, such as their frequency and spatial area of impact, the basic and advanced levels of the framework consist of different risk-management actions for each of the natural hazards.

For landslide hazards, the basic level of analysis involves an initial quantitative estimation of the landslide risk that workers or visitors are exposed to using simple and limited input datasets and data analysis, as well as the impact to assets. An advanced level of analysis involves a quantification of the risk from landslide hazards, involving greater time and resources dedicated towards data collection, input datasets, data analysis and peer review of the risk calculation process. The Part 3 and Part 4 reports outline a methodology for undertaking quantitative risk analysis for both basic and advanced levels.

As outlined in the Part 5 report for tsunami, the basic level involves site-specific assessment of risk-mitigation options that can be cheaply and easily implemented. Advanced-level analysis involves a quantitative estimation of the tsunami risk that workers or visitors are exposed to. This advanced-level analysis is an area of current research.

As outlined in the Part 6 report for volcanic and geothermal hazards, the basic level consists of qualitative risk analysis, which should highlight and identify the potential impacts to persons on the public conservation lands and waters and potential impacts to DOC infrastructure.

The advanced level of analysis involves a site-specific detailed quantitative estimation of the risk from volcanic hazards that workers or visitors are exposed to.

An expert panel is recommended to assess the risk-analysis reports, risk-evaluation and risk-mitigation activities occurring across the different sites of the public conservation lands and waters. This panel may review the results of the preliminary screening tool and corroborate or note the level of analysis required at a site, as well as review the results of the different levels of natural hazard risk analysis and provide advice on any further analysis that might be needed. The expert panel may comprise of relevant DOC staff, an experienced engineering geologist with expertise in natural hazard quantitative risk analysis and professionals with specific technical expertise (e.g. tsunami scientist).

The information in this report is aimed at DOC staff to help inform their decision making around risk-management considerations, as well as commissioning and setting the scope of natural hazard risk analyses.

1.0 INTRODUCTION

1.1 Report Background

The number of people visiting public conservation lands and waters (Department of Conservation [DOC]-managed land) in New Zealand is increasing overall, with some locations being more in demand than others. Many of these visitors and visitor sites are exposed to natural hazards. In addition to increasing visitor usage of existing DOC sites, there is also an ongoing need to replace infrastructure and take into account the effects of climate change. For these reasons, there is an increasing need to carry out risk analyses to: (1) identify and define 'high risk' areas, (2) help DOC manage the risk to visitors at 'high risk' locations and (3) inform visitors of the levels of risk they may be exposing themselves to from natural hazards when accessing these sites.

Previously, there has been no standard risk analyses methodology or metrics implemented by DOC to allow them to consistently assess the risk from natural hazards across the different sites within public conservation lands and waters. Alongside this, no standard risk-tolerance criteria have been established. This has led to a wide variety of analyses methods, metrics and report styles used, thus making it difficult for DOC to consistently assess and use the results nationwide.

In 2008, GNS Science produced a geological site assessment process for huts and campgrounds for DOC (Hancox 2008). This used qualitative assessment and risk ratings for assessing the risk from landslides at points (individual hut sites). However, while this 2008 procedure is adequate for assessing hazards and risk in a qualitative way, it does not provide a consistent methodology for quantifying visitor risks at all sites. As such, DOC wishes to ensure that the most suitable analyses methodology is applied to each situation, which in turn ensures that decision makers are given the right characterisation of risk to aid in making informed and consistent risk-management decisions across public conservation lands and waters.

1.2 Purpose of the Report

The purpose of this report is to:

1. Outline the natural hazard risk-management and risk-analysis frameworks for landslide, tsunami and volcanic hazards, with these enabling informed and consistent risk-management decisions to be made across public conservation lands and waters.
2. Provide technical guidance on the use of the framework for identifying and prioritising risk-management actions for each of the natural hazards.
3. Provide technical guidance on setting the scope of natural hazard analysis.

The information in this report is aimed at DOC staff to help inform their decision making around risk-management considerations and commissioning natural hazard risk analyses. Consultants undertaking risk analysis on public conservation lands and waters may also find it useful to have access to this report in order to understand the principles of the natural hazard risk-analysis framework.

1.3 Scope of Report

The report includes an overview of:

1. The risk-analysis method framework for linear features (such as tracks or roads) and point features (such as huts or viewing platforms) in the public conservation lands and waters.
2. The risk metrics used and risk comparisons.
3. The purpose and structure of the proposed DOC expert panel – established to assess the results from the various risk analyses.
4. Advice on how to set out the scope of the natural hazard analysis projects required by DOC.

In addition, this report outlines how the different risk-analysis methods proposed for landslide, volcano and tsunamic risk fit together to give a comprehensive view of the risk to a site from the hazards analysed. The natural hazard risk-analysis framework is primarily focused on life-safety considerations and risks.

1.4 Structure of the Guidelines

The risk-analysis guidelines are structured as follows:

1. This report (Part 1: Risk-Analysis Framework), providing an overview of the natural hazard risk-analysis framework and methodology.
2. Three reports for landslide hazard risk analysis:
    a. A report (Part 2: Preliminary hazard and exposure analysis for landslides) detailing the methodology required to undertake a preliminary hazard and exposure analysis; ‘a screening tool’ for hazard and exposure analysis that identifies further risk-management actions, prioritisation of risk analyses and advice on, for example, whether basic, advanced or no further risk analyses are needed.
    b. A ‘guideline’ report (Part 3: A guideline on analysing landslide risk to point and linear features) that sets out the proposed methodology for carrying out the basic and advanced risk analyses for both point and linear features within a given study area.
    c. A commentary report (Part 4: A commentary on analysing landslide risk to point and linear features) that accompanies the guideline report and provides additional details on aspects of the hazard and risk analyses. The commentary also provides examples of, and access to, relevant datasets which are provided as case examples. Access to these example datasets will improve the consistency of the output of the consultants by providing them with information that GNS Science and others have been collating, analysing and assessing over the years. As such, the commentary should be seen as a ‘live’ document and will need to be periodically updated on a 2–5-year basis to provide the most up to date scientific information.
3. A report (Part 5: Preliminary hazard and exposure analysis for tsunami) for tsunami hazard risk analysis that contains the necessary background information and methodology required to undertake preliminary hazard and exposure analysis as a screening tool for identifying further risk-management actions, including more detailed risk analysis.

4. A report for volcano hazard risk analysis (Part 6: Preliminary hazard and exposure analysis for volcanoes) that contains the necessary background information and methodology required to undertake preliminary hazard and exposure analysis as a screening tool for identifying further risk-management actions, including more detailed risk analysis.

It was suggested that, after the risk-analysis method had been in use for two years, DOC and GNS Science review the method structure and details and provide any necessary modifications to the method where needed. The first such meeting was held on 13 August 2021, which was attended by Don Bogie, Meryl Jupp (DOC), Saskia de Vilder, Chris Massey (GNS Science), Robin Fell (University New South Wales), Don Macfarlane (AECOM New Zealand) and Tim Davies (University of Canterbury).

1.5 Terminology

The hazard risk terminology adopted for the natural hazard risk-analysis framework is derived from the International Society for Soil Mechanics and Geotechnical Engineering (ISSMGE), the International Society for Rock Mechanics (ISRM) and the International Association of Engineering Geologists (IAEG) Joint Technical Committee working group (JT-C1), as outlined in Corominas et al. (2015) and Fell et al. (2008). The main terms used within all reports include:

- **Hazard:** a condition that expresses the probability of a particular threat (peril) occurring within a defined time period and area.
- **Risk:** a measure of the probability and severity of an adverse effect to life, health, property or the environment. Quantitatively, Risk = Hazard × Potential Worth of Loss. This can be also expressed as ‘Probability of an adverse event times the consequences, if the event occurs’.
- **Risk analysis:** the use of available information to estimate the risk to individuals, populations, property or the environment from hazards. Risk analyses generally contain the following steps: definition of scope, danger (threat) identification, estimation of probability of occurrence to estimate hazard, evaluation of the vulnerability of the element(s) at risk, consequence analysis and their integration.
- **Quantitative risk analysis:** an analysis based on numerical values of the probability of occurrence of a potentially damaging event and vulnerability of the exposed elements and consequences, resulting in a numerical value of the risk.
- **Elements at risk:** population, buildings and engineering works, infrastructure, environmental features, cultural values and economic activities in the area affected by an event (e.g. landslide).
- **Exposure:** people, property, systems or other elements present in hazard zones that are thereby exposed to potential losses.
- **Spatio-temporal probability of the element at risk**: the probability that the element at risk is in the path of a hazard at the time of its occurrence. It is the quantitative expression of the exposure.
- **Vulnerability:** the degree of loss of a given element or set of elements exposed to the occurrence of a hazard of a given magnitude/intensity. It is often expressed on a scale of 0 (no loss) to 1 (total loss).

2.0 RISK-MANAGEMENT FRAMEWORK

This section outlines DOC's risk-management approach and how the natural hazard risk-analysis methodology fits within the overall risk-management workflow. The following excerpt from the DOC (2025) visitor-safety-management standard operating procedure states:

> *"Outdoor activities always involve some risk. DOC does not try to eliminate all risk, as making sites completely safe would not be reasonably practicable, would damage natural and cultural values, and limit visitor freedom. Instead, DOC manages risk to an acceptable level for the site's intended use against set risk thresholds. Hazards are only managed if the risk from them exceeds the acceptable level for the site type.*
>
> *There are three acceptable risk thresholds for visitor sites on PCLW* [public conservation lands and waters]*. These apply to all types of visitor risk assessment. The thresholds correspond to the type of visitor site and its intended use."*

Figure 2.1 Schematic displaying the level of risk management for different types of visitor sites.

2.1 Risk-Analysis Framework

2.1.1 Overview

The aim of natural hazard risk analysis is to answer the following questions:

1. What can happen at a site, how large is the hazard and how likely (frequently) will it occur? This includes hazards that have occurred and the 'unknown' hazard that could occur in the future.
2. If the hazard occurs, what is the likelihood that a person / multiple people will be impacted? What is the likelihood that an asset is impacted?
3. If people are impacted, what is the likelihood that they will be killed?

This applies to landslides, tsunami and volcano hazards. Figure 2.2 shows a more detailed framework for landslides, but the overall framework is applicable for the other hazards analysed in this project. The natural hazard risk-analysis framework outlined in Figure 2.3 is designed to provide a consistent approach to analysing natural hazard risk across the public conservation lands and waters. The framework consists of three levels:

1. Preliminary screening.
2. Basic analysis and/or risk mitigation.
3. Advanced analysis and/or risk mitigation.

It is intended that the hazards at a site are initially analysed using the Part 2, 5 and 6 preliminary screening methodology reports, which contain the preliminary screening methodology for the landslide, tsunami and volcanic hazards, respectively. The purpose of the preliminary screening methodology is to determine whether more analysis and/or risk mitigation is needed at a site and assist in assigning priority to such analyses. The preliminary screening methodology consists of identifying at the site:

1. The specific hazards that could affect the site.
2. The magnitude and area affected (how big will it be if it were to occur?).
3. The frequency of occurrence (how often could it occur?).

The consequence from the hazards is evaluated using two exposure metrics:

1. **Spatio-temporal probability of a visitor**: the proportion of time (P) over a trip that the individual of interest spends at a given hazard level at the site.
2. **Spatio-temporal probability of a worker:** the proportion of time (P) over a year that the worker of interest spends at a given hazard level at the site.

The hazard information is combined with the exposure metrics to assign a hazard and exposure class for a site. The purpose of the relative hazard and exposure matrix is to help DOC prioritise the sites in terms of future investigations and analysis and whether these should be (i) basic or (ii) advanced, as well as what requirements/measures may be needed to manage the risk. The relative hazard and exposure matrices are broadly based on the risk-management framework contained in the original Risk Management Guidelines Companion to AS/NZS 4360:2004, which is now superseded by 31000:2009 (AS/NZS 2009). At this preliminary analysis stage, for landslide hazards only, societal exposure (e.g. how many people are exposed to the hazard and for how long?) should be considered internally by DOC both before the analysis is undertaken and as part of the expert panel discussion (see Section 2.2).

Due to the different characteristics of the natural hazards, such as their frequency and spatial area of impact, the basic and advanced levels of the framework consist of different risk-management actions for each of the natural hazards. Sections 2.3–2.5 outline for each natural hazard the different levels of the risk-analysis framework.

For all hazard types, if hazards have already been identified as a concern at the site by DOC and/or if it is important for DOC to have an understanding of cumulative risk along a linear feature, the preliminary screening process may be bypassed with basic or advanced levels of analysis undertaken as the next risk step (Figure 2.3).

For each level of the natural hazard risk-analysis framework, it is proposed that a DOC expert panel, consisting of a mixture of internal and external safety and technical experts, will review the analyses and provide advice for further risk-management action, including more advanced risk analysis. Further information on the DOC expert panel is provided in Section 2.2. Any further risk-management actions, including risk analysis, are at the discretion of DOC on the advice of the expert panel. Figure 2.4 outlines the respective roles of the consultant and DOC staff throughout the risk-analysis and risk-management process.

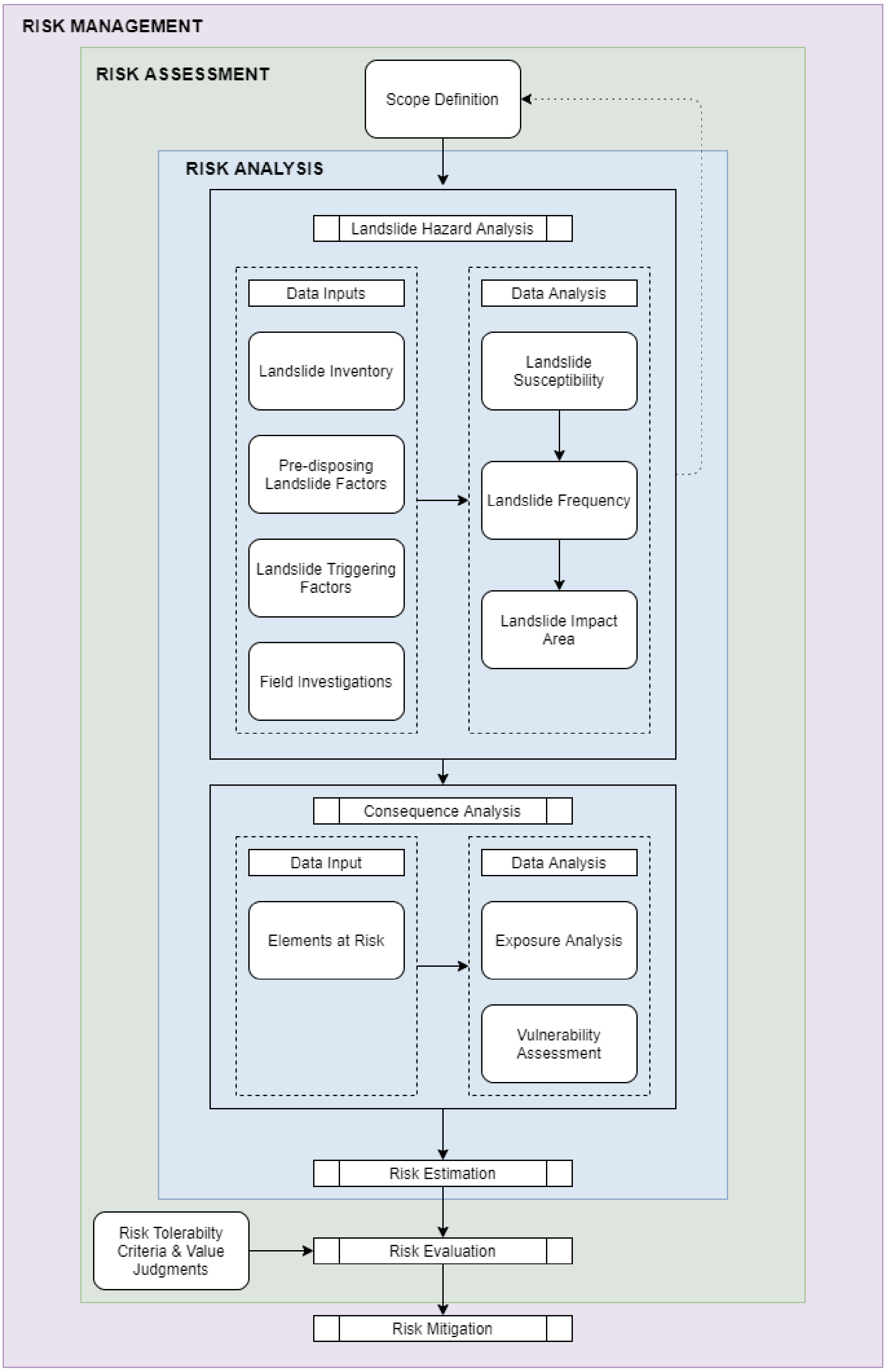

Figure 2.2 Landslide risk-management framework, with similar frameworks applicable for tsunami and volcanic hazards (adapted from AGS [2007]; AS/NZS [2009]).

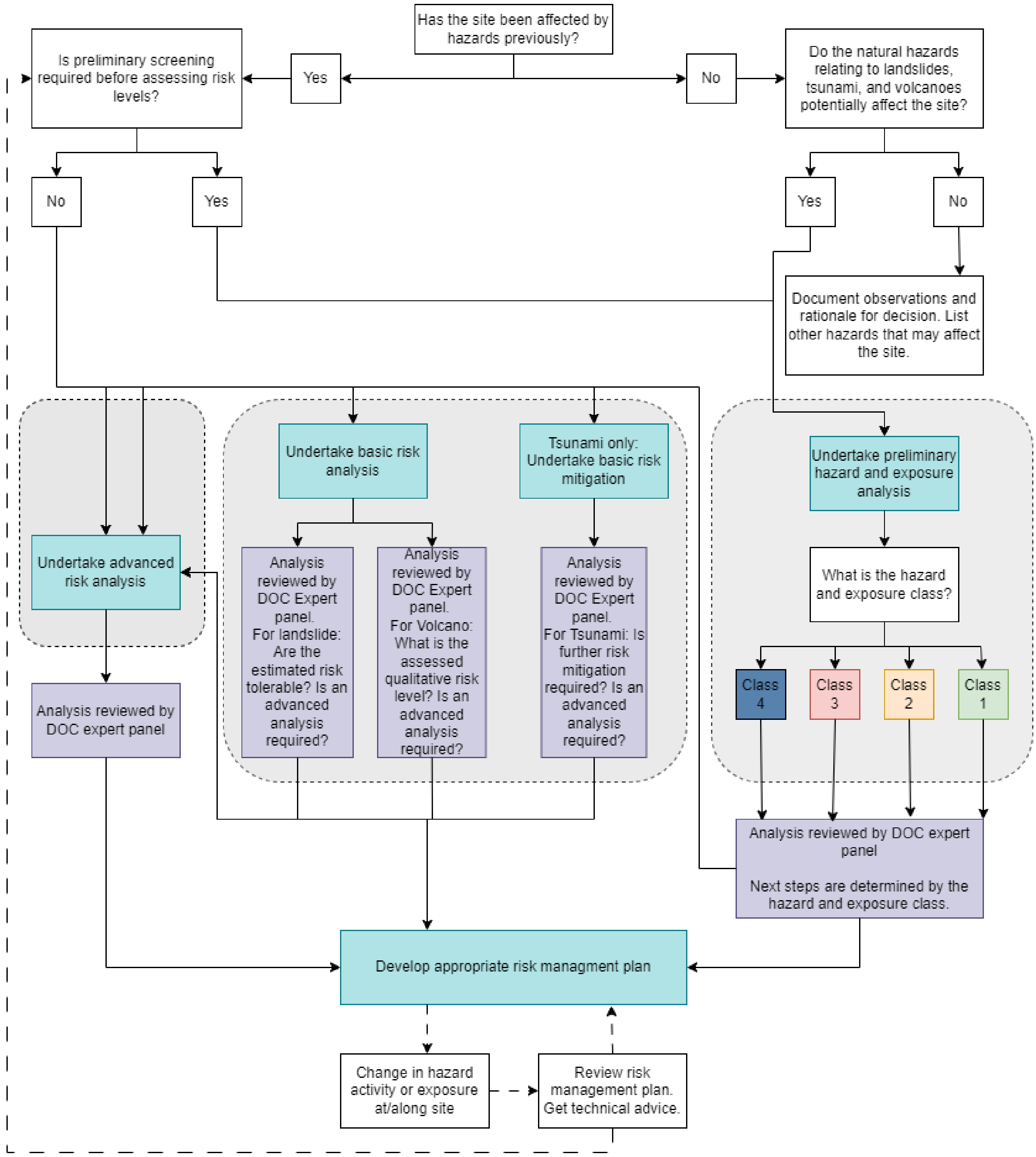

Figure 2.3 Flowchart of the natural hazard risk-analysis framework, outlining the three different levels of risk analysis. The green text boxes represent actions, the purple text boxes represent review stages, the red text box and arrows represent the recommended actions from a Class 3 and Class 4 rating, the orange text box and arrows represent recommended actions for a Class 2 rating and the blue text box and arrows represent the recommended actions for a Class 1 rating.

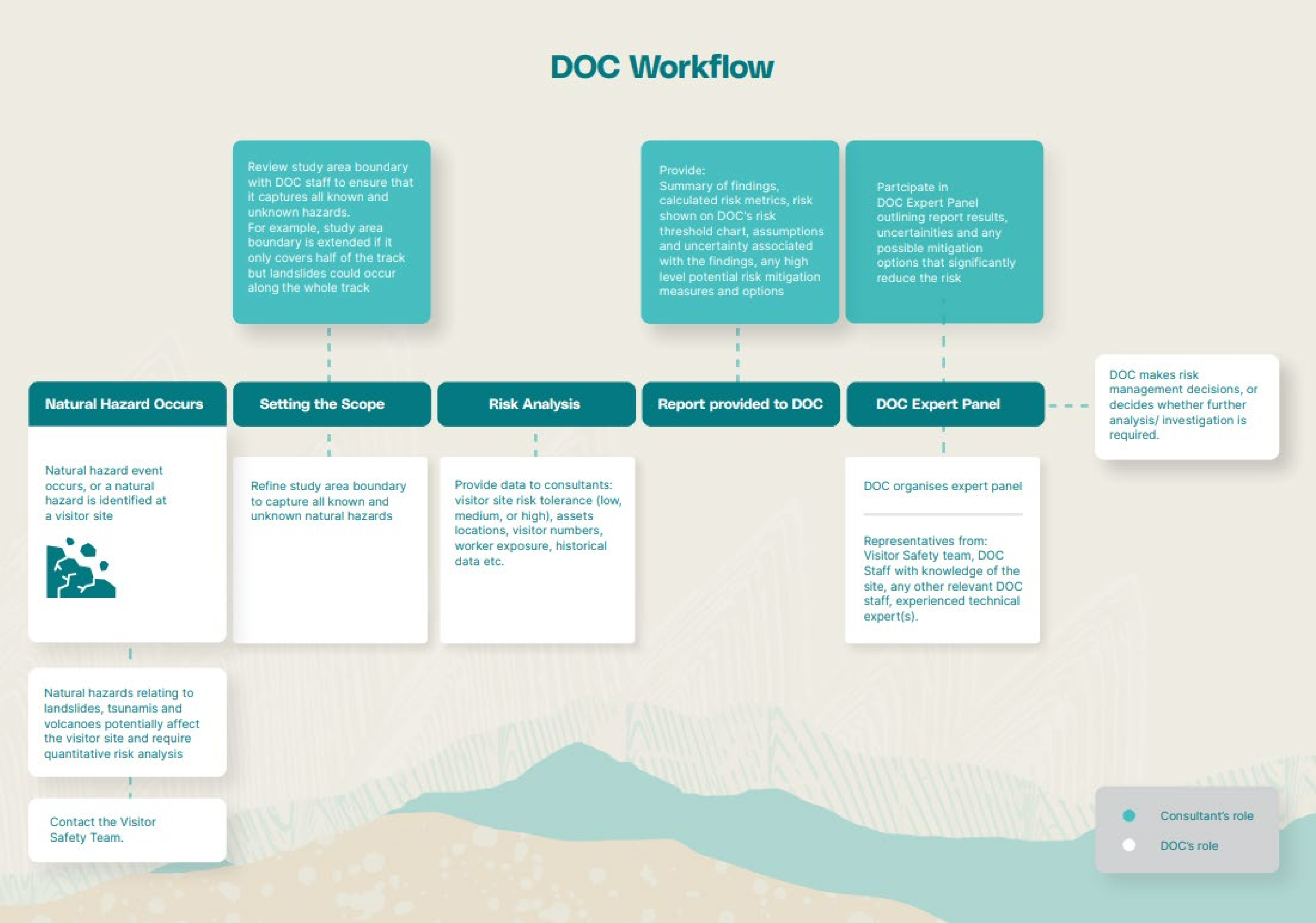

Figure 2.4 The role of the consultant and Department of Conservation staff within the natural hazard risk-analysis framework.

2.1.2 Department of Conservation Expert Panel

The purpose of this panel is to assess the risk-analysis reports, risk-evaluation and risk-mitigation activities occurring across the different sites of the public conservation lands and waters. This includes:

- Review of the results from the screening tool and corroboration or not of the level of analysis required at a site. For preliminary landslide hazard and exposure analysis, this will include a discussion on the DOC internal estimate of societal exposure to the hazard and associated risk using information provided from the consultant report.
- Review of the results from the different levels of the natural hazard risk-analysis framework and provision of advice on any further analysis that might be needed.
- Provision of guidance on what risk-management procedures may be adopted at each site and oversight to ensure such procedures are applied consistently across all of DOC.
- Provision of input for other considerations that need to be taken into account, such as management plans; natural features; and heritage, biodiversity and other visitor values.

The expert panel may comprise:

- Relevant DOC staff (covering a wide range of the appropriate issues).
- DOC staff with knowledge of the site.
- An experienced engineering geologist or geotechnical engineer with expertise in quantitative risk analyses who has strong connections to other relevant experts and therefore can request their advice when needed.
- Specific technical expertise (for example, a geotechnical engineer, tsunami scientist, volcanic hazard specialist …).

It is anticipated that the makeup of the panel may change with time / the nature of the analysis and hazards being analysed.

The panel may also consider further risk analysis and risk-management decisions from natural hazards not included within the initial preliminary or basic levels of the natural hazard risk-analysis framework. For example, tsunami generated by causes other than earthquake, such as volcanic eruptions or landslides, which are not covered by the basic tsunami risk analysis. In this example, it may be particularly important to identify this hazard and potential risk, if the landslide basic- or advanced-level analysis identifies that a substantial volume of landslide debris could enter a ‘large’ body of water.

The panel should meet as and when needed. In some cases, DOC should have an established alternative process, whereby, after the preliminary or basic-level analysis, the advanced level can be fast-tracked without waiting for the panel to convene.

2.1.3 Landslides

2.1.3.1 Preliminary Screening Analysis

The Part 2 report of these guidelines presents a method to identify: (1) the different types of landslide hazards that could affect the site, (2) their potential magnitude (how big they could be) and hazard footprint (area affected by the landslide) if it were to occur and (3) the frequency of occurrence, which is how often it could occur. This includes identifying whether a site could be affected by slippage or falling debris hazards, which are terms mentioned in Building Act 2004 and used in this report as:

1. **Slippage:** includes the movement or loss (including partial loss) of land from a slope when it occurs beneath, for example, a structure, path, road, car park, etc.
2. **Falling debris:** includes soil, rock, vegetation and snow or ice that may fall and ‘runout’ onto a site from upslope (the landslide source area), inundating the site.

The areas of slippage and falling debris are defined in order to determine the hazard footprint, and therefore the number of people that may be exposed within the footprint(s) for the different hazard types. The hazard temporal probability (Table 2.1) and exposure (Table 2.2) are then used to define the hazard class (Class 1–4) for a site, based on the hazard and exposure matrices. The hazard and exposure class is a guide to what level of future analysis is required, as outlined in Table 2.3.

At this preliminary analysis stage, societal exposure (e.g. how many people are exposed to the hazard and for how long?) will be considered internally by DOC as part of the expert panel discussion. DOC will collate information on the number of people exposed and how long they are exposed using information on the hazard footprint and frequency of the event, provided by the consultant as part of their report, to inform the DOC estimates of societal exposure and risk.

Table 2.1 Quantitative and qualitative descriptors of landslide temporal probability (based on Hancox [2008]).

Indicative Recurrence Interval (Years)	Relative Temporal Probability
<1	**Extremely High:** Hazard event will likely occur multiple times a year
1–10	**Very High:** Hazard event will very likely occur in the near future
10–100	**High:** Hazard event is likely to occur
100–1000	**Medium:** Hazard event could possibly occur
1000–10,000	**Low:** Hazard event is unlikely to occur
>10,000	**Very Low:** Hazard event occurs rarely

Table 2.2 Risk-management actions and associated hazard and exposure class for landslide hazards.

Proportion of Time Spent at a Given Hazard Level in 24 Hours	This Approximately Equals:	Example Activity
>0.1	More than 3 hours	Staying at a hut
0.1–0.01	From ½ an hour to 3 hours	Picnic spot
0.01–0.001	From 2 minutes to ½ an hour	Stopping at viewing area
0.001–0.0001	From 10 seconds to 2 minutes	Crossing a swing bridge
<0.0001	Less than 10 seconds	Walking past a given point (e.g. 1 m^2)

Table 2.3 Risk-management actions and associated hazard and exposure class for landslide hazards.

Class	DOC Risk-Reduction-Response Categories	Risk-Management Actions
Class 1	No risk reduction required (beyond standard measures) but monitor for changes	No further risk analysis required. DOC should develop appropriate risk-management plans and re-evaluate the risk-management plan if there is a change in hazard activity or the number of people exposed.
Class 2	Reduce to as low as reasonably practicable	Basic level of risk analysis required. The analysis should highlight and identify the potential impacts to persons on the public conservation lands and waters. Identified high-risk sites may require further advanced-level risk analysis and consideration of mitigation options.
Class 3	Continue only after high-level review	Urgent action is required. This may involve interim risk-management solutions (e.g. closures) while solutions are developed. Basic-level risk analysis must be undertaken and an advanced-level risk analysis may be required.
Class 4	Close the site (using a formal closure process)	Class 4 represents the highest priority for further risk analysis and risk-management actions. Urgent action is required. This may involve interim risk-management solutions (e.g. closures) while solutions are developed. Basic-level risk analysis must be undertaken and an advanced-level risk analysis may be required.

2.1.3.2 Basic Analysis

The Part 3 and Part 4 reports present a best-practice method for quantitatively determining the risk to individuals and groups of people (including people within vehicles) and assets at a basic level: (1) along linear (tracks and roads) sites and (2) at point sites (huts, carparks, viewing areas, etc.) within the public conservation lands and waters.

A basic level of analysis represents an initial quantitative estimation of the landslide risk that workers or visitors are exposed to, as well as impacts to assets, using simple and limited input datasets and data analysis.

The steps in a basic-level risk analysis are:

1. Identify hazard types.
2. Estimate likelihood of hazards.
3. Estimate consequences if the hazard were to occur.
4. Derive appropriate risk metrics.

Due to the simplified level of analysis, the estimated risk from the basic analysis is inherently more uncertain, so the risk estimates may span several orders of magnitude. For example, the estimated annual individual fatality risk (AIFR) may be 10^{-4} (1 chance in 10,000 of being killed per year), but the uncertainty on the estimate may range between 10^{-3} and 10^{-5} (1 chance in 1000 to 1 in 100,000). The DOC risk-tolerability criteria should be provided to the consultant, against which they can plot the results from their basic-level analysis. The consultant can identify and recommend feasible risk-mitigation options.

Such analysis may be site-specific, for example, at the location of a hut or bridge, but they could also be at the local and regional scale – for example, along an entire walking track – and could be used to determine areas along the track that may need a more advanced level of analysis.

2.1.3.3 Advanced Analysis

An advanced level of analysis involves a quantification of the risk from landslide hazards, involving greater time and resources dedicated toward data collection, input datasets, data analysis and peer review of the risk calculation process, as outlined in the Part 3 and Part 4 reports. Advanced-level analysis can be directed toward specific locations and sections along linear site studies, where the additional cost is warranted to refine boundaries of risk zones and the estimates of risks, as well as assist in design of risk-reduction measures for those locations and high-risk point sites. Such analysis may be site-specific but could also be at the local scale, for example, an advanced level of analysis may be carried out for a section of a walk that could be several kilometres in length, e.g. Cape Kidnappers. The uncertainty associated with these estimated risk values may be reduced. Additionally, the DOC risk-tolerability criteria will be provided to the consultant against which they can plot the results from their advanced-level analysis. Following this, the consultant can identify and recommend feasible risk-mitigation options and the resulting risk reduction and residual risks. The DOC expert panel will determine which study areas with basic-level analysis require further advanced-level analysis.

2.1.4 Tsunami

2.1.4.1 Preliminary Screening Analysis

The Part 5 report presents a desktop-based method for analysing the magnitude of the tsunami hazard and exposure of people to tsunami generated in the oceans and seas around New Zealand by large earthquakes. Earthquake-generated coastal tsunami hazards sites that are above 40 m in elevation or are more than 8 km inland may be immediately identified as having negligible hazard and excluded from the risk analysis. The tsunami risk analysis therefore only includes coastal shorelines less than 40 m in elevation and less than 8 km inland. The assessed shoreline should include all tidal coastlines (i.e. including tidal estuaries, harbours, sounds, fjords, lagoons and so forth, as well as the open coast).

The method assesses the frequency with which tsunami could occur that may potentially inundate the site. Data on tsunami hazard at the coast from the 2021 National Tsunami Hazard Model (2021 NTHM; Power et al. 2022) is used in combination with empirical formulae, developed for evacuation zoning, to outline locations that are potentially[1] subject to inundation. The hazard level (Table 2.4) and exposure are then used to define the hazard class (Class 1–3) for a site based on the provided hazard and exposure matrices. The hazard and exposure class is a guide to what level of future analysis and mitigation is required, as outlined in Table 2.5.

1 The data and methods available for the preliminary analysis are conservative, and advanced analysis may find lower levels of inundation hazard.

Table 2.4 Quantitative and qualitative descriptors of tsunami hazard level.

Hazard Criteria – Site is Potentially Inundated by Tsunami at the Following Return Periods:	Hazard Level
<100 year	High
100–1000 year	Medium
1000–2500 year (at 84% confidence) **Or**, if a tsunami evacuation map exists: 1000 year – event(s) used to delineate the Yellow tsunami evacuation zone	Low
>2500 year (at 84% confidence) **O**r, if a tsunami evacuation map exists: Larger than the event(s) used to delineate the Yellow tsunami evacuation zone	Very Low

Table 2.5 Risk-management actions and associated hazard and exposure class for tsunami hazards.

Class	DOC Risk-Reduction-Response Categories	Risk-Management Actions
Class 1	No risk reduction required (beyond standard measures) but monitor for changes	No further risk analysis required; however, DOC should develop appropriate risk-management plans, and re-evaluate the risk-management plan if there is a change in hazard activity or the number of people exposed.
Class 1*	No risk reduction required (beyond standard measures) but monitor for changes	No further risk analysis required. These sites are outside of the tsunami evacuation zone, so risk mitigation by evacuation is not expected. Information and evacuation maps displayed at popular locations in this category may still reduce the risk to visitors or staff who travel to the coast from these sites.
Class 2	Reduce to as low as reasonably practicable	Basic risk-mitigation analysis required. For tsunami, the basic analysis will determine if a further quantitative risk analysis (‘Advanced’ analysis) is required. The distinction between classes 2 and 3 is used in the basic analysis to determine the acceptable level of risk mitigation.
Class 3	Continue only after high-level review	
Class 4	Close the site (using a formal closure process)	An advanced risk analysis study is required. The Basic risk-mitigation analysis will also be required as a pre-requisite to provide data to inform the advanced analysis.

2.1.4.2 Basic Risk Mitigation

There is currently no standardised method for the quantification of risk from tsunami and so no method is presented to quantify the risk from tsunami at either a basic or advanced level of analysis. Quantitative risk analysis of tsunami is an area of current research.

As such, basic-level analysis involves a site-specific analysis of risk mitigation from tsunami generated in the oceans and seas around New Zealand by large earthquakes. This involves fieldwork and site-specific consideration of mitigation options at the site, with particular regard to communication of warning (including information for identifying natural warnings), evacuation routes and evacuation maps. This will be used to assess the level of risk mitigation that can be achieved at the site.

The Part 5 report contains more information about what is required for the basic risk-mitigation analysis. The analysis identifies the potential range of tsunami sources, which may be informed by the deaggregation charts in the 2021 NTHM (Power et al. 2022) and travel times of tsunami from these sources to the site. The potential for other hazards to be present after or following an earthquake (e.g. landslides, bad weather) should also be considered.

The basic risk mitigation should identify whether easily and cheaply implemented risk mitigation options (such as improving signage and communication) can satisfactorily reduce the risk, or if more complicated/expensive mitigation measures are necessary. The Part 5 report contains recommendations on levels of risk reduction that need to be achieved for each hazard class (e.g. 90% of occupants at a site can be evacuated in the event of a tsunami for sites with a hazard and exposure class rating of 2). Therefore, the effectiveness of the available mitigation options should be assessed using the hazard and exposure class identified by the preliminary screening tool, taking into account the potential for warning and evacuation. An advanced level of analysis should be undertaken after the basic risk-mitigation level if engineering mitigation works are required or if the basic risk mitigation was not capable of suggesting adequate mitigation options for the site (e.g. no evacuation routes under steep coastal cliffs). The DOC expert panel will determine which study areas with basic risk mitigation requires further advanced-level analysis.

2.1.4.3 Advanced Analysis

An advanced level of analysis involves the quantification of risks from tsunami generated in the oceans and seas around New Zealand by large earthquakes. It may also include a quantification of risk from tsunami generated by other mechanisms, such as submarine landslides, volcanic eruptions, landslide-generated tsunami within fjords and sounds, and seiches generated within lakes. This is a highly specialised activity at the forefront of current research. The basic risk-mitigation analysis should be conducted first, both to establish if the advanced analysis is required and to provide information needed to inform the advanced quantified analysis. Additionally, the DOC risk-tolerability criteria will be provided to the consultant/researcher, against which they can plot the results from their advanced-level analysis. Following this, the consultant/researcher can identify and recommend feasible risk-mitigation options and the resulting risk reduction and residual risks.

2.1.5 Volcanic Hazards

2.1.5.1 Preliminary Screening Analysis

The Part 6 report presents a desktop-based method for analysing the volcanic hazard and exposure of people to the volcanic hazard. Two categories of volcano and geothermal eruptions are considered:

- **Category A:** Eruptions with no useful precursory activity that indicate an eruption is imminent. These are a concern at geothermal areas and/or volcanoes with shallow magma near the surface (within upper 2 km). These steam-driven eruptions are sometimes called ‘unheralded’ or ‘blue-sky eruptions’.
- **Category B:** Eruptions preceded by escalating volcanic unrest, thus providing advanced knowledge about the likely location and size of volcanic activity.

The hazard from Category A eruptions is based solely on distance from source areas, while, for Category B eruptions, the hazard level is based on eruption frequency within a specified distance from source regions. The hazard frequency classification is based on a conservative assessment of how likely the hazard caused by volcanic or geothermal area activity may occur at the site. The method assesses hazard and exposure at both point and linear sites.

The hazard level (Table 2.6) and exposure are then used to define the hazard class (Class 1–3) for a site, based on the hazard and exposure matrices. The hazard and exposure class is a guide to what level of future analysis is required, as outlined in Table 2.7.

Table 2.6 Quantitative and qualitative descriptors of volcanic eruption temporal probability for Category B.

Indicative Recurrence Interval (Years)	Description
<100	High
100–1000	Medium
1000–10,000	Low
>10,000	Very Low

Table 2.7 Risk-management actions and associated hazard and exposure class for volcanic hazards.

Class	Risk-Management Actions
Class 1	No further risk analysis required; however, DOC should develop appropriate risk-management plans and re-evaluate the risk-management plan if there is a change in hazard activity or the number of people exposed.
Class 2	Basic level of risk analysis required, involving a site-specific qualitative analysis of risk from volcanic hazards. The analysis should highlight and identify the potential impacts to persons on the public conservation lands and waters and potential impacts to DOC infrastructure. Identified high-risk sites may require further advanced-level risk analysis and consideration of mitigation options. It is important to understand that volcanic risk is often dynamic and can rapidly change over a period of hours to several years.
Class 3	Advanced level of risk analysis requires a site-specific detailed quantitative analysis of risk from volcanic hazards. Class 3(a) represents the highest priority for further risk analysis and risk-management actions.

2.1.5.2 Basic Risk Analysis

There is currently no New-Zealand-wide standardised method for the quantification of risk from volcanoes and so no method is presented to quantify the risk from volcanoes at either a basic or advanced level of analysis.

As such, the basic-level risk analysis involves a site-specific qualitative analysis of risk from volcanic hazards. This generally involves the creation of hazard maps for several eruption scenarios and/or a hazard magnitude–frequency assessment for one or more specific hazards. The analysis should highlight and identify the potential impacts to persons on the public conservation lands and waters and potential impacts to DOC infrastructure. Qualitatively identified high-risk sites may require further advanced risk analysis and consideration of mitigation options. It is important to understand that volcanic hazards are often dynamic, so the risk to people and infrastructure can rapidly change over a period of hours to several years. The Part 6 report contains more information on dynamic risk and volcanic risk-management plans.

2.1.5.3 Advanced Risk Analysis

For volcanoes, quantified risk analysis may include an estimation of risks from volcanic hazard and eruptions. There is a published peer-reviewed method for assessing life-safety risk at active (unrest or erupting) volcanoes (Deligne et al. 2018). A similar approach formed the basis of risk assessments undertaken by GNS Science for DOC following the Te Maari eruptions of 2012 (Jolly and Taig 2012; Jolly 2013). This approach was developed with a focus on so-called 'unheralded eruptions' (Category A), that is, eruptions with no useful precursory activity that indicates an eruption is imminent. Application of the methodology requires an understanding of:

1. The magnitude–frequency distribution of eruptions at nearby volcano(es).
2. The types of eruptions and sizes of eruptions could occur at nearby volcano(es).
3. The potential for a new vent (geothermal or volcanic) to open up at a site or close to a site.
4. The types of volcanic hazards, their frequency in different credible eruption scenarios and their likely severity and impacts.
5. The risk metrics to be used (see Section 2.6) and timeframe of interest.
6. The types of mitigative measures that can reduce risk to tolerable levels and the residual risk if the mitigative measures would be implemented.

These points are valuable information for any volcanic life-safety risk analysis, not just the approach presented in Deligne et al. (2018).

2.2 Risk Metrics

The natural hazard risk analysis framework requires that the following risk metrics should be used for basic and advanced risk analysis of landslide hazards, as well as advanced risk analysis for tsunami and volcanic hazards. The metrics should be used where requested by DOC for the appropriate analysis. These metrics are as follows:

1. **The local personal risk (LPR)**, which represents the annual probability of death for a theoretical imaginary person present at a particular location for 100% of the time (24 hours a day and 365 days of the year). It is a useful metric to visualise the spatial distribution of risk within a given study area and can be used to help plan/re-align tracks and roads.
2. **The annual individual fatality risk (AIFR)**. This is expressed in terms of the fatality risk experienced by an individual (probability of death) over one full year of working or visiting in a given study area. The risk is calculated for: (1) the worker(s) most exposed and (2) the visitor most exposed, e.g. a person who may do a walk several times a year. A 'worker' is an inclusive term for any person undertaking work-related activity on public conservation lands and waters, which can include DOC staff, DOC volunteers, DOC contractors and concessionaires.
3. **Individual risk per day or per experience of up to one day for visitors**. This is expressed in terms of the fatality risk experienced by an individual (probability of death) per day or per experience, if the walk takes several days, along a track and/or road within the given study area.
4. **Multiple fatality risk**. This is defined as the relationship between the frequency of occurrence of a specified hazard and the number of people in a given population being killed if the hazard were to occur (Lee and Jones 2014). At some sites, a key issue could be that a large landslide, or several smaller landslides triggered by a single event

such as an earthquake, could cause multiple fatalities in a single event. Multiple fatality risk is scenario-based. Two broad risk metrics are considered for multiple fatality risk, which includes:

a. **fN:** fN pairs or curves are calculated by linking some specific scenarios that relate the number of people who might be in a group with the likelihood of them being killed if a hazard of a given magnitude were to occur (N) and the frequency of the hazard occurring (f). For basic analysis, this is presented as a series of fN pairs. For advanced analysis, multiple fN pairs can be calculated and combined to create an FN curve that is then plotted on a diagram, where 'F' is the frequency of any/all scenarios with greater than or equal to N fatalities occurring.

b. **Annual Probable Lives Lost (PLL):** The product of probability (f) and number of fatalities (N) yield probable life loss (PLL). PLL describes the expected number of deaths over a period of time. PPL from various independent risk scenarios (e.g. fN pairs) can be summed to yield the total PLL for an assessed hazard or study area. If probability is presented as an annual probability, then it is the annual probable life loss. The annual probability of life loss should be calculated for one fatality, five fatalities and the worst-case scenario.

The risk metrics used are generally relatively small in terms of the likelihood of a particular individual being killed per year. Thus, the risk analyses reports should present the risk in terms of numbers such as 10^{-4} ('10 to the power of minus 4') per annum. Table 2.8 shows how some of these numbers translate into more familiar terms and may be useful to keep on hand for readers who are not familiar with this terminology.

Table 2.8 Translation of the '10 to the power of minus … per year' terminology into other terms.

10 to the power of minus … per year'	Is the same as (per year):	Is approximately the same as once in:	Is the same as:
10^{-3}	0.001 or 0.1%	1000 years	8% per lifetime [2]
10^{-4}	0.0001 or 0.01%	10,000 years	0.8% per lifetime
10^{-5}	0.00001 or 0.001%	100,000 years	0.08% per lifetime
10^{-6}	0.000001 or 0.0001%	1,000,000 years	0.008% per lifetime

2.3 Risk Tolerability and Risk Comparators

The natural hazard risk-analysis method provides risk estimates from the different geological hazards experienced across the public conservation lands and waters, from which DOC can assess and evaluate the tolerability of the risk and potential risk-mitigation options. Risk evaluation and risk mitigation will be undertaken by DOC staff, with input from the consultant.

In the context of risk evaluation, the estimated risk metrics from the risk analysis, in particular, the advanced analysis, can be compared against other risks that workers and visitors may experience, such as:

1. Fatalities on the public conservation lands and waters itself.
2. Risks from other natural hazards (in New Zealand in particular).
3. Workplace risk (in New Zealand).
4. General mortality and morbidity statistics (New-Zealand-specific).

2 Based on average New Zealand life expectancy of about 80 years, from 2008 mortality and population data.

5. Popular tourist activities in New Zealand.
6. Other sport and leisure activities (in New Zealand).
7. Travel to and from DOC sites.
8. Fatalities in National Parks and the ‘great outdoors’, generally in other countries.

Taig (2022a, 2022b) outlines and establishes relevant risk comparators for DOC and provides advice on setting risk-tolerability criteria. The use of risk comparators is used to inform DOC’s decision making around risk tolerability. DOC has set risk-tolerability levels based on the guidance in Taig (2022a, 2022b). These comparators, tested against contemporary risk levels at various DOC visitor sites, helped set the quantitative risk thresholds for different types of visitor sites, which were approved by DOC’s senior leadership. These were then combined into low-, medium- and high-risk-threshold visitor-site categories (Table 2.9; Figure 2.5).

- **Lower-risk-threshold visitor sites:** These are visitor experiences where the visitor has no intention of taking any life-threatening risks. These risks are comparable to activities in places with minimal or no threat to life, such as playing a game of tennis or the safer end of driving (an experienced driver driving to the road rules in a modern car).
- **Medium-risk-threshold visitor sites:** These are visitor experiences where the visitor is not expecting much risk but is aware that, at times, accidents happen. These risks are comparable to activities where occasional fatalities occur, such as swimming and riding a bike, but generally are not thought of as high-risk.
- **Higher-risk-threshold visitor sites:** These are visitor experiences where the visitor is prepared to take a higher level of risk. At the top end of these risks, they are comparable to the death rate of climbing or remote tramping, where unbridged rivers need crossing and rock scrambling is part of the trip. When compared with driving, the risk is comparable to the fatality risk of an inexperienced driver in an older vehicle.

A consistent risk-tolerability criteria across public conservation lands and waters will improve the consistency and transparency of decisions both for DOC (on issues such as whether risk-mitigations measures are needed at a site and, if so, what would be the best approach). The same applies for visitors and users of the public conservation lands and waters (to help inform their own decisions about where they feel it is safe for them to go and what they should do to keep themselves safe).

Table 2.9 Department of Conservation natural hazard risk thresholds for visitor sites.

Natural Hazard Risk Thresholds – three acceptable risk thresholds for quantitative risk assessments	
Risk Threshold	**Type of DOC Visitor Site**
Lower Risk	• Short walks • Walking tracks • Grade 1 and 2 cycle trails • Campsites • Amenity areas
Medium Risk	• Easy tramping tracks, including Great Walks • Grade 3 and 4 cycle trails • Promoted marine sites, such as Goat Island
Higher Risk	• Tramping tracks • Routes • Grade 5 and 6 cycle trails

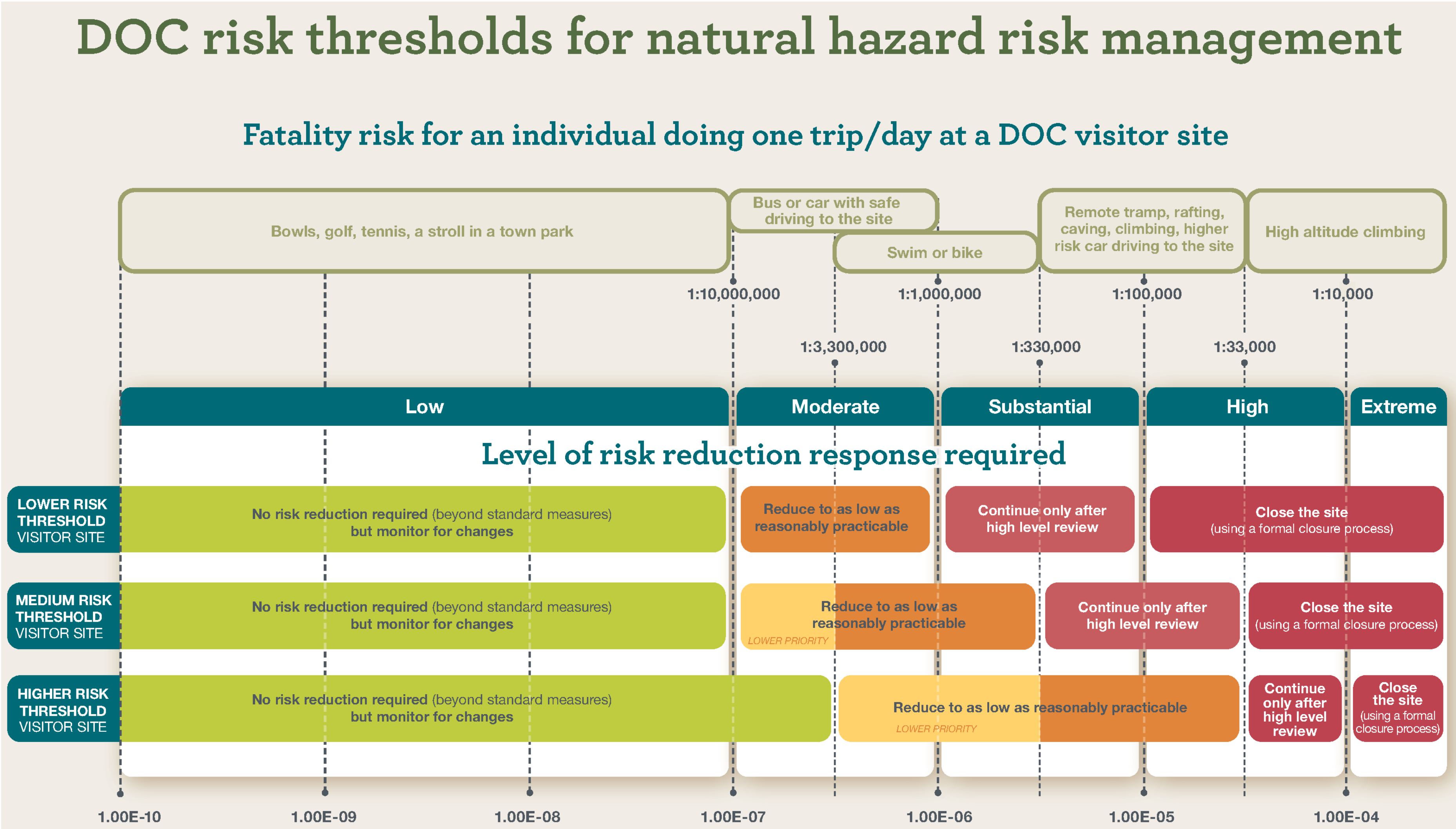

Figure 2.5 Department of Conservation natural hazard risk thresholds for visitor sites and associated risk-reduction response.

Once a quantitative natural hazard risk assessment is completed, the risk figures from the consultant's findings are plotted against DOC's natural hazard risk thresholds. Depending on the site's risk acceptability, DOC's response will be (as outlined in Figure 2.6):

- No risk reduction required.
- Reduce to as low as reasonably practicable.
- Continue only after high-level review.
- Close the site.

Natural hazard risk reduction response

What the risk reduction response categories mean for DOC:	
No risk reduction required (beyond standard measures)	**Risk is low.** • Follow DOC's normal visitor asset management and visitor safety communication standards. • Informally monitor for changes.
Reduce to as low as reasonably practicable	**Operations Manager leads a team process to establish suitable mitigations.** • Use local team and experts to decide on necessary actions using the hazard management guideline. • Ensure that the mitigations selected are proportional to the risk. Avoid costly and resource intensive measures. • Reassess the risk if the hazard changes – a formalised monitoring regime may be required to identify changes.
Continue only after high level review	**Regional Director leads a team process to understand if the risk is acceptable and establish mitigations.** • Use local team and experts to identify suitable risk reduction options. • Consider significant changes to reduce risk like moving infrastructure. • A Trigger Action Response Plan (TARP) may be needed, along with a formal monitoring regime to identify changes and respond to increased risk. • Close the site using the Visitor Safety Closures SOP if risk cannot be reduced to an acceptable level.
Close the site	**Close the site using the Visitor Safety Closures SOP.** • Regional Director and experts across DOC decide the site's future. Brief the Senior Leadership Team on the discussions and decisions made. • Unless the site can be redesigned to eliminate the risk (such as moving a hut or rerouting a track), permanent closure and disposal of the site's assets is very likely at this risk level.

Figure 2.6 The four Department of Conservation risk-reduction-response categories and associated internal actions.

3.0 GUIDANCE ON SCOPING NATURAL HAZARD RISK ANALYSIS

3.1 When to Use the Natural Hazard Risk-Analysis Methodology

DOC has an internal visitor risk-management standard operating procedure and a guideline that are used by DOC staff to determine when a quantitative analysis of risk is required, as set out in the natural hazard risk-analysis methodology, and when a qualitative analysis of risk is required, such as the Hancox (2008) hut screening tool.

The DOC (2025) visitor-safety-management standard operating procedure states that the natural hazard risk-analysis methodology should be used in situations where an in-depth analysis is needed to quantify the amount of risk from natural hazards. These analyses could include:

1. Developing a new visitor site or making significant investment in one.
2. Noting that landslide risk is ongoing and this risk needs to be understood.
3. Noting that it cannot be determined whether the risk is acceptable using a Site Control Plan.
4. Deciding whether the risk can be reduced or whether the site needs major changes or closure.

This DOC visitor-safety-management standard operating procedure also outlines situations where the quantification of risk from the natural hazard risk-analysis methodology may not be appropriate. These situations could include where the:

1. Landslide risk is no longer present.
2. Risk is already known to be acceptable.
3. Focus is on engineering or repair options rather than risk quantification.
4. Site Control Plan assessment is enough to understand the risk.

3.2 Setting the Scope of the Natural Hazard Risk Analysis

The initial study area boundary will be set by DOC when they initially scope the work. This boundary will be approximate and will need to be refined; however, it should include known hazards (e.g. landslides that have occurred) and unknown hazards (e.g. landslides that could occur). This should be done at several stages and refined as/when needed. The preliminary screening tool should identify the study area boundaries based on the extent of the identified hazard footprints and the site being assessed.

It should be noted that there may be multiple hazard zones within the study area boundary, within which there may be several hazard footprints. A Hazard Zone is defined as: an area of ground within which the topography/morphology, geology, geomorphology and hazard types are similar. These differ from Hazard Footprints, which are defined as the area of ground that could be affected by a particular type of hazard that could occur within a hazard zone. Therefore, a study area may contain multiple hazard zones, within which there may be multiple hazard footprints. For example, where a site may be exposed to both rockfall and debris flow (landslide) hazards or even non-landslide hazards, such as tsunami or volcano hazards.

The screening tool can be used to identify hazard zones and footprints within a larger study area boundary, the level of analysis required for the site(s) within them and the scale of analysis, from regional to site-specific.

3.3 Provision of Data

DOC should provide the following visitor and worker information to the geotechnical consultant:

1. The study area boundary and locations of the specific huts, tracks, roads, etc., in GIS format.
2. The number of visitors walking the tracks, including:
   a. the seasonality of this number (e.g. peak versus off-season visitor numbers), and
   b. the average time spent walking the tracks.
3. The number of visitors staying at a hut, including:
   a. the seasonality of this number (e.g. peak versus off-season visitor numbers), and
   b. the average length of stay.
4. The number of visitors driving along the road, including:
   a. the length of time it takes them to drive the road, and
   b. the composition of vehicles (e.g. cars versus buses).
5. The number of hours spent by workers walking along the tracks or driving along the roads.
6. Any locations along the tracks/roads that visitors and/or workers may spend longer at (such as a picnic area or viewing point), including:
   a. the number of visitors parked at another point source site, such as a picnic spot or carpark, and the length of time the visitor spends at the locations; and
   b. the number of hours spent by workers at a particular point site.
7. The visitor risk threshold of the linear or point site.
8. How an emergency warning message would currently be communicated to visitors and workers at location.

This information should be provided from DOC observations and records (e.g. track counters, traffic counts, walking times). If there are limited data, DOC should make their best estimate and provide likely ranges. Where available, DOC should provide GIS data (and associated metadata) for track and road positions.

Additionally, DOC should provide any other relevant information DOC owns for conducting the risk analysis that is not available publicly, including historical information, such as:

1. Fatalities and/or near-miss events along the linear site or at the point site.
2. Observations and/or records of landslides, tsunami and volcanic events.
3. Previously commissioned natural hazard and geotechnical reports.
4. Any meteorological data, such as rain gauge records.
5. Topographic information for the slopes.
6. Design and construction information for roads (managed by DOC and not under the jurisdiction of NZTA or local territorial authorities) or any other engineering works previously undertaken.
7. Any existing arrangements for the mitigation of natural hazards, e.g. tsunami evacuation signage.

3.4 Peer Review Requirements

3.4.1 Preliminary and Basic Analysis

For a preliminary basic-level risk analysis, the peer review requirements should consist of an internal review by a competent, independent consultant. As part of the DOC expert panel, DOC will also provide a ‘high-level’ quality check on the report.

3.4.2 Advanced Analysis

For advanced-level analysis, an external peer-reviewer is required. This provides DOC with greater confidence that the risk analysis is of sufficient quality and fit for purpose. This peer-review process should be ongoing from the risk-analysis investigation through to the closure of the project. The external peer-review process may require a field visit.

4.0 CONCLUSION

This report presents a natural hazard risk-analysis framework for landslide, tsunami and volcanic hazards that can potentially impact sites on public conservation lands and waters (DOC-managed land), such as huts, visitor centres, tracks and roads. The natural hazard risk-analysis framework is concerned with life-safety considerations and life-safety risk to both visitors and workers on public conservation lands and waters, as well as impacts to assets on public conservation lands and waters.

The natural hazard risk-analysis framework is designed to provide a consistent approach to analysing natural hazard risk across the public conservation lands and waters.

The GNS Science risk-analysis reports comprise:

- Part 1: Risk-Analysis Framework (this report)
- Part 2: Preliminary hazard and exposure analysis for landslides
- Part 3: A guideline on analysing landslide risk to point and linear features
- Part 4: A commentary on analysing landslide risk to point and linear features
- Part 5: Preliminary hazard and exposure analysis for tsunami
- Part 6: Preliminary hazard and exposure analysis for volcanoes.

It is intended that the hazards at a site are initially analysed using the preliminary screening methodology. The Part 2, Part 5 and Part 6 reports contain the preliminary screening methodology for each natural hazard. The purpose of the preliminary screening methodology is to determine whether more analysis and/or risk mitigation is needed at a site and to assist in assigning priority to such analyses. This includes determining if the future risk investigations or analysis should be (i) basic or (ii) advanced, as well as what requirements/measures may be needed to manage the risk. Due to the different characteristics of the natural hazards, such as their frequency and spatial area of impact, the basic and advanced levels of the framework consist of different risk-management actions for each of the natural hazards.

For landslide hazards, the basic level of analysis involves an initial quantitative estimation of the landslide risk that workers or visitors are exposed to using simple and limited input datasets and data analysis. An advanced level of analysis involves a quantification of the risk from landslide hazards, involving greater time and resources dedicated towards data collection, input datasets, data analysis and peer review of the risk calculation process. The Part 3 and Part 4 reports outline a methodology for undertaking quantitative risk analysis for both basic and advanced levels.

For tsunami, the basic level of analysis involves site-specific assessment of risk-mitigation options that can be cheaply and easily implemented. Advanced-level analysis involves a quantitative estimation of the tsunami risk that workers or visitors are exposed to. This advanced-level analysis is an area of current research.

For volcanic and geothermal hazards, the basic level of analysis consists of qualitative risk analysis, which should highlight and identify the potential impacts to persons on the public conservation lands and waters and potential impacts to DOC infrastructure. The advanced level of analysis involves a site-specific detailed quantitative estimation of the risk from volcanic hazards that workers or visitors are exposed to.

For each level of the natural hazard risk-analysis framework, it is proposed that a DOC expert panel, consisting of a mixture of internal and external safety and technical experts, will review the analyses and provide advice for further risk-management action, including more advanced risk analysis. It was suggested that, after the risk-analysis methodologies have been in use for two years, DOC and GNS Science review the framework, including the methods within the framework, and provide any necessary modifications to the framework and/or methods where needed. The first such meeting was held on 13 August 2021, which was attended by Don Bogie, Meryl Jupp (DOC), Saskia de Vilder, Chris Massey (GNS Science), Robin Fell (University New South Wales), Don Macfarlane (AECOM New Zealand) and Tim Davies (University of Canterbury). Revised versions of the Part 1–5 reports were issued in June 2024.

The report also provides technical guidance on scoping the natural hazard analysis, providing appropriate data to the consultants undertaking the analyses and outlining the peer-review requirements for the work. The information presented in this report is aimed at DOC staff to help inform their decision making around risk-management considerations, as well as commissioning and setting the scope of natural hazard risk analyses.

5.0 ACKNOWLEDGEMENTS

This report has been internally reviewed by Dr Sam McColl. Previous versions of the report have been peer-reviewed by Dr Marc-Andre Brideau (formerly GNS Science), Emeritus Professor Robin Fell (University New South Wales, Sydney) and Mr Don Macfarlane (AECOM New Zealand, Christchurch). GNS Science appreciates the assistance provided by the independent reviewers through their comments on the draft guidelines. All comments have received careful consideration and many improvements have been made to the guidelines as a result. However, GNS Science acknowledges that any comments made by the reviewers were non-binding. Ultimately, the final decisions with regards to any diversity of views between co-authors and internal reviewers and external reviewers were made by the lead author of each document in consultation with the co-authors.

6.0 REFERENCES

[AGS] Australian Geomechanics Society. 2007. Guideline for landslide susceptibility, hazard and risk zoning for land use management. *Australian Geomechanics*. 42(1):13–36.

[AS/NZS] Standards Australia, Standards New Zealand. 2009. Risk management: principles and guidelines. 3rd ed. Sydney (AU): Standards Australia. 26 p. AS/NZS ISO 31000:2009.

Corominas J, Einstein H, Davis T, Strom A, Zuccaro G, Nadim F, Verdel T. 2015. Glossary of terms on landslide hazard and risk. In: Lollino G, Giordan D, Crosta GB, Corominas J, Azzam R, Wasowski J, Sciarra N, editors. *Engineering Geology for Society and Territory – Volume 2*. Cham (CH): Springer International Publishing. p. 1775–1779.

Deligne NI, Jolly GE, Taig T, Webb TH. 2018. Evaluating life-safety risk for fieldwork on active volcanoes: the volcano life risk estimator (VoLREst), a volcano observatory's decision-support tool. *Journal of Applied Volcanology*. 7(1):7. https://doi.org/10.1186/s13617-018-0076-y

[DOC] Department of Conservation. 2025. Visitor safety management SOP. Wellington (NZ): DOC. DOC-7555122. 21 p.

Fell R, Corominas J, Bonnard C, Cascini L, Leroi E, Savage WZ. 2008. Guidelines for landslide susceptibility, hazard and risk zoning for land use planning. *Engineering Geology*. 102(3–4):85–98. https://doi.org/10.1016/j.enggeo.2008.03.022

Hancox GT. 2008. Revised geological hazard and risk assessment method for DOC backcountry hut sites and camp sites. Lower Hutt (NZ): GNS Science. 31 p. Consultancy Report 2008/256. Prepared for the Department of Conservation.

Jolly GE. 2013. Update to risk assessment for visitors walking on the Tongariro Alpine Crossing, February 2013. Lower Hutt (NZ): GNS Science. 10 p. Consultancy Report 2013/38LR. Prepared for the Department of Conservation.

Jolly GE, Taig T. 2012. Risk assessment for Department of Conservation staff working on the Tongariro Alpine Crossing track near Ketetahi and for visitors walking on the Tongariro Alpine Crossing Track. Lower Hutt (NZ): GNS Science. 19 p. Consultancy Report 2012/310. Prepared for the Department of Conservation.

Lee EM, Jones DKC. 2014. Landslide risk assessment. 2nd ed. London (GB): ICE Publishing. 509 p.

Power WL, Burbidge DR, Gusman AR. 2022. The 2021 update to New Zealand's National Tsunami Hazard Model. Lower Hutt (NZ): GNS Science. 63 p. (GNS Science report; 2022/06). https://doi.org/10.21420/X2XQ-HT52

Taig T. 2022a. Guidelines for DOC on dealing with natural hazard risk. Cheshire (GB): TTAC Ltd. 91 p.

Taig T. 2022b. Risk comparisons for DOC visitors and staff. Cheshire (GB): TTAC Ltd. 131 p.

www.gns.cri.nz

Principal Location

1 Fairway Drive, Avalon
Lower Hutt 5010
PO Box 30368
Lower Hutt 5040
New Zealand
T +64-4-570 1444
F +64-4-570 4600

Other Locations

Dunedin Research Centre
764 Cumberland Street
Private Bag 1930
Dunedin 9054
New Zealand
T +64-3-477 4050
F +64-3-477 5232

Wairakei Research Centre
114 Karetoto Road
Private Bag 2000
Taupo 3352
New Zealand
T +64-7-374 8211
F +64-7-374 8199

National Isotope Centre
30 Gracefield Road
PO Box 30368
Lower Hutt 5040
New Zealand
T +64-4-570 1444
F +64-4-570 4657