A companion document to Toka Tū Ake EQC's Risk Tolerance Methodology

Natural Hazard Risk Tolerance Literature Review

July 2023

This document has been developed by the Toka Tū Ake EQC Risk Reduction and Resilience Team and comprises an extensive literature review and discussion paper.

Te Kāwanatanga o Aotearoa
New Zealand Government

Toka Tū Ake EQC

Toka Tū Ake EQC has a role to facilitate natural hazard research and education, and to contribute to the sharing of information, knowledge, and expertise in relation to natural hazard risk management, prevention or reduction of natural hazard impacts, and community resilience to natural hazards.

To help Aotearoa New Zealand communities understand their risk tolerance, so they can make better decisions.

Executive Summary

Robust and transparent hazard risk management processes, that include assessing risk tolerance, are important to manage and reduce risk effectively. Understanding risk tolerance is a critical part of the hazard risk management process.

Aotearoa New Zealand does not have a consistent approach to assessing risk tolerance or risk thresholds. Effective risk management identifies the boundaries between 'acceptable', 'tolerable', and 'intolerable' risks. A consistent approach to assessing risk tolerance would help Toka Tū Ake EQC to:

- proactively support risk reduction to reduce our liability,
- develop risk thresholds in the Natural Hazards Portal[1], and
- guide and contribute to the Government's direction on setting risk thresholds.

This paper starts by outlining the difference between risk tolerance and risk thresholds:

- Risk tolerance is an organisation or stakeholder's readiness to bear a risk with or without risk treatment to achieve its objectives.
- Risk threshold is a limit beyond which a risk is treated differently.

The Introduction presents **basic terminology** including risk tolerance and risk thresholds and describes why Toka Tū Ake EQC has an interest in them.

What is risk? summarises **key features of hazard risk**. The CDEM Act defines risk as the likelihood and consequence of a hazard, which should be broken down to understand exposure and vulnerability.

Levels of risk discusses **risk level terminology**, especially terms used in Aotearoa New Zealand. Risk tolerance terminology is **highly varied** at national and sub-national levels and is **not consistent** across agencies or policies.

Once risk threshold terminology has been agreed, the risk can be measured and evaluated against pre-determined criteria. The following section outlines how risk can be measured. discusses various **methodologies to measure risk**, including their advantages and limitations.

Risk to what gives direction on **what risks can be assessed**, based on the legislative themes of wellbeing: health and safety, economic, cultural, property, and environmental.

[1] The Natural Hazards Portal will be a public facing, 'self-service' natural hazard risk and risk management information website. Its tools will make it easy for users to understand natural hazard risks against their risk tolerance and empower them to make risk-informed decisions. Phase 1 of the Natural Hazards Portal will be launched in 2023, and functionality including risk tolerance assessment will be integrated into the Natural Hazards Portal over the following two to three years.

Risk to whom outlines approaches to assessing **who is at risk** from both individual and societal perspectives. When assessing either individual or societal risk, we must first determine the risk tolerance of the people at risk.

Risk perception compares ‘perceived’ and ‘actual’ risk and considers the role **risk perception** plays in risk management. Risk perception may ultimately be more important than actual risk in affecting behaviour and choices. A high degree of trust in decision-makers and risk communicators is vital to change behaviour or prompt action.

Risk tolerance discusses the three necessary elements for robust engagement on risk tolerance: process, interpretation, and transparent integration of outcomes. It also gives an example of how tolerability can be assessed.

Determining risk thresholds gives examples of international and national thresholds for life safety and compares the associated annual individual fatality rates. Both international and national risk-to-life thresholds are **highly variable** and **context-specific**.

Various context-specific methodologies, in Aotearoa New Zealand and internationally, are used to determine risk thresholds. Including risk tolerance in Aotearoa New Zealand’s hazard risk management framework calls for a **nationally consistent approach to assessing risk tolerance, including setting risk thresholds** with the following key features:

1. **The risk analysis process should be documented and result in a clear level of risk.** Existing risk analysis processes can be used, which allow different sectors to follow best practice for the specific context or hazard. The risk analysis should be documented and result in a clear level of risk (e.g., ‘intolerable’, ‘tolerable’, or ‘acceptable’) so the resulting level of risk can be considered against risk thresholds.

2. **Risk thresholds should be pre-set through an agreed process**. Specific classifications of risks would be established across different settings (e.g., impacts to people, the economy, the environment, etc.) for specific timeframes. This would allow the results of the risk analysis to be assessed against consistent risk thresholds to determine risk tolerance.

3. **Policy options should directly align with agreed risk threshold terminology.** Consistent terminology across policy would allow certain levels of risk to directly correspond with certain treatment options. For example, ‘intolerable’, ‘tolerable’, and ‘acceptable’ risks could correspond with ‘removal’, ‘reduction’, or ‘monitoring’ policy response options, respectively. This would create more consistent risk management outcomes, while accommodating specific hazards and context.

4. **Risk treatment should be implemented through engagement based on the policy options available for the risk tolerability.** This enables communities to decide which risk treatment option is implemented, while providing national consistency on policy approaches used for different levels of risk tolerance. For example, where national legislation specifies a ‘tolerable’ level of risk, regional or district level policies can provide the appropriate response (e.g., reduction, adaptation, or monitoring).

This literature review and discussion paper is a starting point for wider discussion and collaboration, on integrating a nationally consistent approach to assessing risk tolerance within Aotearoa New Zealand's risk management framework.

Based on this literature review, the 2023 Toka Tū Ake EQC companion paper "Risk Tolerance Methodology" provides a method for integrating a risk tolerance assessment into current hazard risk management approaches, i.e., at the evaluation stage of the risk assessment process (typically based on ISO 31000:2018). It provides consistency while being adaptable to suit varying contexts and timeframes, including for decision-makers across local, regional, and central government levels, and within the private sector. This will enable more robust and transparent risk-based decision-making. The paper also proposes nationally consistent risk terminology for risk tolerance.

Contents

Abbreviations

AAL	Average annual losses
AEP	Annual exceedance probability
AIFR	Annual Individual Fatality Risk
ALARP	As low as reasonably practicable
APR	Annual property risk
ARI	Average recurrence interval
CDEM	Civil Defence Emergency Management
DIA	Department of Internal Affairs
DOC	Department of Conservation
DP	District plan
DPMC	District of Prime Minister and Cabinet
DRF	Disaster risk financing
DRM	Disaster risk management
EAL	Expected annual losses
EQC	Toka Tū Ake EQC
GDP	Gross domestic product
HSE	(United Kingdom) Health and Safety Executive
HSWA	Health and Safety at Work Act 2015
ISO	International Organisation for Standardisation
LGA	Local Government Act 2002
LGNZ	Local Government New Zealand
MBIE	Ministry of Business, Innovation, and Employment
MfE	Ministry for the Environment
NEMA	National Emergency Management Agency
NZ	Aotearoa New Zealand
PCBU	Person conducting a business or undertaking

PCC	Porirua City Council
PCL	Public conservation lands (and waters)
PML	Probable maximum loss
RMA	Resource Management Act 1991
RPS	Regional policy statement
SFAIRP	So far as is reasonably practicable
TOR	Tolerability of risk (framework)
UP	Unitary Plan
VOSL	Value of statistical life
WCC	Wellington City Council

Introduction

Risk tolerance is an organisation or stakeholder's readiness to bear a risk after risk treatment to achieve its objectives (ISO, 2009b). It involves assessing why we choose to accept, transfer, avoid, or reduce risk. It helps us understand how to respond when a hazard event affects the things we value (like our health, environment, economy, and buildings or infrastructure). So, to help people at risk of natural hazard events in Aotearoa New Zealand with making decisions, we need to understand their risk tolerance.

To manage risk, we need to understand risk tolerances. But Aotearoa New Zealand does not have an agreed local, regional, or national approach to assessing risk tolerance and risk acceptability.

A common understanding of risk thresholds and a consistent approach (or set of approaches) to determining them would help the roles and responsibilities for managing natural hazard risks across Government (e.g., through the RMA, Building Act 2004, LGA, CDEM Act, and EQC Act). It would also help develop new policies, including reviews and reforms of the RMA, Building Act 2004, and CDEM Act. Risk tolerance and risk threshold criteria are important parts of risk management.

The aim of this paper is to guide and contribute to the Government's direction on setting risk thresholds (e.g., RMA reform) and to inform the development of the Natural Hazards Portal (refer below).

To meet this aim, we consider the following questions:

1. What is risk?
2. How can risk be measured?
3. What are risk thresholds, and why are they important?
4. What is the relationship between risk thresholds and risk tolerance?
5. How are risk thresholds determined, internationally and in Aotearoa New Zealand?
6. Who determines risk thresholds?
7. What national direction is needed?

This discussion paper builds on, and is intended to be read in conjunction with, the 2021 GNS Science Consultancy Report *"Stocktake of Existing Risk Tolerance Frameworks"* (Clarke et al., 2021), commissioned by MfE. It broadens the scope beyond climate change and makes further comparisons between international and national practice for thresholds, terminology, and approaches.

This literature review is based on publicly available information, or permission has been granted to use it. The scope of this report is does not include all risk management considerations, for example risk appetite, uncertainties, how to balance competing interests when deciding risk thresholds, or managing residual risks.

We have used the following definitions of risk terms in this paper:

- Risk: the likelihood and consequences of a hazard (CDEM Act 2002);
- Risk appetite: the amount and type of risk that an organisation or person is willing to pursue or retain (ISO, 2009b);
- Risk tolerance: an organisation or stakeholder's readiness to bear the risk after risk treatment to achieve its objectives (ISO, 2009b);
- Risk threshold: a limit beyond which the risk is treated differently (adapted from Project Cubicle, 2022); and
- Level of risk: a qualitative descriptor of the magnitude of a risk, like 'low, 'medium', 'high, or 'acceptable', 'tolerable', 'intolerable'.

This discussion paper focuses on risk tolerance and associated thresholds.

Why is Toka Tū Ake EQC interested in risk tolerance and risk thresholds?

The Crown and Toka Tū Ake EQC manage the financial risk to Aotearoa New Zealand from natural hazard events and poor risk-based decisions. This means we have a significant interest in making sure Aotearoa New Zealand manages natural hazard risks better and invests in evidence-based risk reduction incentives and initiatives.

The EQCover building cap increased in October 2021. This makes it even more important for us to maintain the Natural Disaster Fund so Aotearoa New Zealand can continue to respond and recover financially when natural hazard events occur. We can support this by actively reducing natural hazard risk across the country to contribute to communities' wellbeing.

As part of this work, Toka Tū Ake EQC is developing the Natural Hazards Portal to address the issues Aotearoa New Zealand faces when translating, sharing, promoting, and using hazard risk information. The Natural Hazards Portal will be a public facing, 'self-service', natural hazard risk and risk management information site. It will offer a comprehensive view of Aotearoa New Zealand's natural hazard risks, at an individual, community, local, regional, and national level. It will leverage the data, information, and risk-modelling capability Toka Tū Ake EQC owns or funds, and data held by others, including government agencies.

A key aspect of the Natural Hazards Portal will be to encourage and support risk-informed decision-making. We need to support individuals, communities, and organisations to consider their risk tolerance. To do this, we need to identify any hazards that affect them and then show them ways to avoid, control, transfer, or manage their risk(s). Toka Tū Ake EQC is developing a risk tolerance assessment function as part of the Natural Hazards Portal so individuals, businesses, engineers and builders, local and central government officials, and communities can understand what a risk might mean for them in practical terms.

Risk tolerance and risk thresholds

Risk tolerances and risk thresholds are interlinked – we need one to understand the other.

Determining both risk tolerances and risk thresholds comes under the 'risk evaluation' stage of the risk management process, as shown in Figure 1.

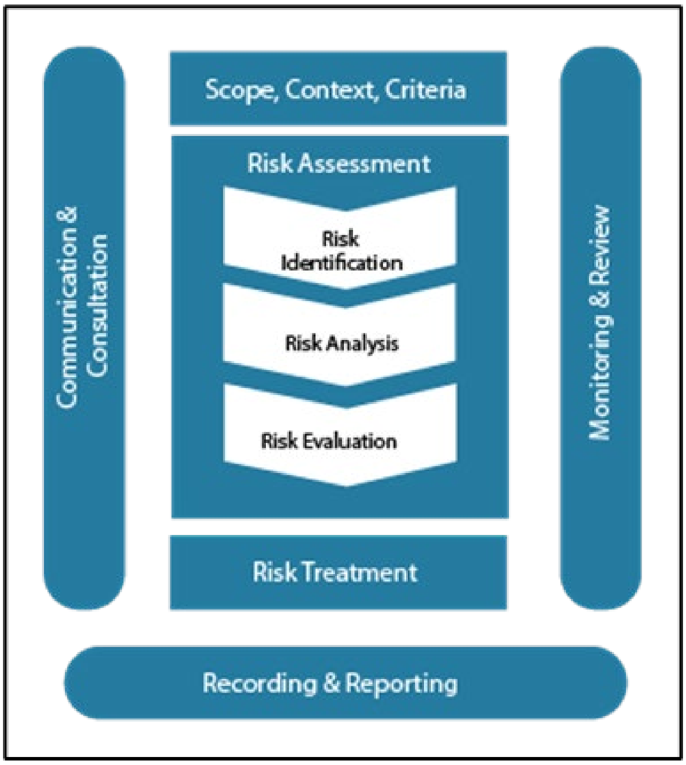

Figure 1 - The ISO31000 risk management process (SNZ, 2018)

Risk evaluation involves considering risk tolerance criteria (e.g., number of injuries or fatalities) against pre-set risk thresholds (e.g., 'acceptable', 'tolerable', or 'intolerable'). Once we complete the risk evaluation, we can determine risk treatment options for each risk classification. The purpose of the risk evaluation is to aid decision making—based on the risk analysis results—about which risks need treatment, and the priority for treatment (ISO, 2018). Risk management is explained in greater detail in Appendix A1 Risk management process.

We must make decisions about risk tolerance with input from communities, experts, iwi, councils, infrastructure providers, and any other key stakeholders (Kilvington & Saunders, 2015).

Determining risk thresholds is a further step in risk evaluation because risk evaluation qualifies or quantifies the risk tolerance. This means that, while risk tolerance guides the limits, the risk thresholds clearly state limits of acceptable or tolerable risk. Determining risk tolerance requires thorough engagement with key stakeholders. To determine risk tolerances, we should consider the wider context of the risk, and the tolerance of affected parties who do not gain any benefit from experiencing the risk. We should make decisions in accordance with legal, regulatory, and other requirements (ISO, 2018).

This paper focuses on approaches to determining risk thresholds – the limit beyond which a risk is treated differently – via the risk evaluation stage of the risk assessment and management process (Figure 1). First the paper discusses risk terminology, including components of risk, levels of risk, and examples of how risk terminology is used. It discusses:

- how risk can be measured,
- what can be measured (i.e., risk to life, property, infrastructure, environment, financial risk, and combined risk metrics),
- who is affected by the risk, both individually and societally, who makes the decision about who is affected, and what key questions should be asked,
- how to assess risk tolerance,
- current practice for determining risk thresholds, both internationally and nationally, and
- summary and next steps.

What is risk?

There are many ways to define risk (for example, CDEM Act 2002; ISO, 2018; IPCC, 2019).

Broadly, risk can be described as the 'effect of uncertainty on objectives', where an effect is any deviation from the expected and can by positive, negative, or both (ISO, 2018). In Aotearoa New Zealand, the CDEM Act defines risk as 'the likelihood and consequences of a hazard'. Consequences are the result of the natural hazard event and its interaction with human life and property. Exposure to life and property from the hazard and the vulnerabilities of each (i.e., pre-existing medical conditions; construction type of building) determine the consequence. Using the definition of risk from the CDEM Act (risk = likelihood x consequence), this section expands on these components of risk. Appendix A2 Auckland Council Toolbox also provides a more detailed explanation.

Likelihood

Likelihood is the probability of something occurring. When describing the likelihood of a natural hazard event, three main descriptors are used:

- **Average recurrence interval (ARI)** – the average period of time between hazard events of a given magnitude, and often referred to as a return period (e.g., a 1-in-100-year event).
- **Probability of exceedance** – the probability that a natural hazard event of a certain size will occur, or will be exceeded, in a given time period. If the time period is one year, it is referred to as an annual exceedance probability (AEP).
- **Frequency of occurrence** – the number of times an event occurs within a specified time interval, for example, the number of flood events in a 100-year time period. Annualised frequency comes from either the number of recorded hazard occurrences each year over a given period or the modelled probability of a hazard occurrence each year.

See Clarke et al. (2021) for detailed explanations of these terms.

Consequence

A consequence can be defined as an impact on our natural, built, and social environments, our economy, or our governance and sovereignty as the result of a hazard event. Consequences are influenced by the **hazard characteristics**, and by the **exposure** and **vulnerability** of the **elements at risk** (e.g., human life or property).

Hazard characteristics

- What hazards could affect elements at risk in a certain area?
- What are the characteristics of those hazards, e.g., the magnitude, duration, extent and speed of onset?
- How do we value the elements potentially at risk of being affected by the natural event (e.g., dollars, function, people's health).

Exposure

- What is the exposure of the elements at risk to the potential hazards?

Vulnerability

- How vulnerable are the elements at risk in the area to each type of hazard?

Elements at risk

- What is actually at risk?
- Can effects on one asset or element have cascading effects to others?

Table 1 - Elements at risk, considered by environment

Environment	Examples of elements at risk
Built	Commercial, residential, and industrial buildings; infrastructure; urban fabric; critical lifeline utilities; and community facilities (schools, hospitals, churches, etc).
Social	Public health; living standards; cultural and social capital; casualties (injuries or deaths of people); community assets and networks; relationships; and support systems.
Economy	Economic growth; financial stability; currency and price; businesses; jobs; trade; and services.
Natural	Air quality; land and marine ecosystems and their services; recreational amenities (e.g., parks); agriculture and horticulture.
Governance and sovereignty	Ability of government agencies to make effective decisions and provide services; law and order; effective international partnerships, treaties and agreements.

Consequences can be described qualitatively (e.g., 'minor', 'moderate', 'severe') or quantitatively (e.g., numbers of deaths or injuries, financial losses, cost of reconstruction, number of jobs lost). The consequences of events can be both positive and negative. For example, an earthquake which destroys many buildings (primary impact is on the built environment) may provide the opportunity for urban renewal and growth in construction sector employment rates (positive for the economic and social environments). There may also be a mix of consequences for the social environment, with casualties, insurance pay-outs, strengthened neighbourhood support networks, and the loss of social services; and the natural environment, with debris disposal, or land-use changes (e.g., from developed to recreational). Determining both positive and negative potential consequences allow us to assess the risk relating to future events.

Levels of risk

There are many ways to describe risk, and there is no standard terminology around levels of risk and thresholds.

A critical part of assessing risks is weighing benefits gained by undertaking the activity against the negative consequences and how often they occur. Broadly, activities that are associated with significant benefits and/or low levels of risk are considered acceptable. On the other hand, activities with benefits that do not justify the potential negative consequences and how often they occur are considered unacceptable.

The following section outlines the 'as low as reasonably practicable' approach to assessing risk. It also shows the inconsistent approach to terminology at national and sub-national levels in Aotearoa New Zealand.

As low as reasonably practicable (ALARP)

For an activity to be 'acceptable' or 'tolerable', the benefits must outweigh the potential negative consequences and frequency. That is, the negative consequences must be reduced or controlled to a reasonable level before it is acceptable or tolerable to undertake the activity (and realise the benefits). This 'reasonable level' of reduction or control is often termed 'as low as reasonably practicable' (ALARP).

The concept of ALARP comes from UK Health and Safety at Work legislation and the Health and Safety Executive (HSE) – it is illustrated in Figure 2. 'So far as is reasonably practicable' (SFAIRP), 'as near as reasonably practicable' (ANARP), and 'as low as reasonably achievable' (ALARA) have also been used at various times and in various settings. They all essentially mean the same thing and are taken to be interchangeable. ALARP seems to be the most enduring and widely used of these terms, so we have used it in this paper.

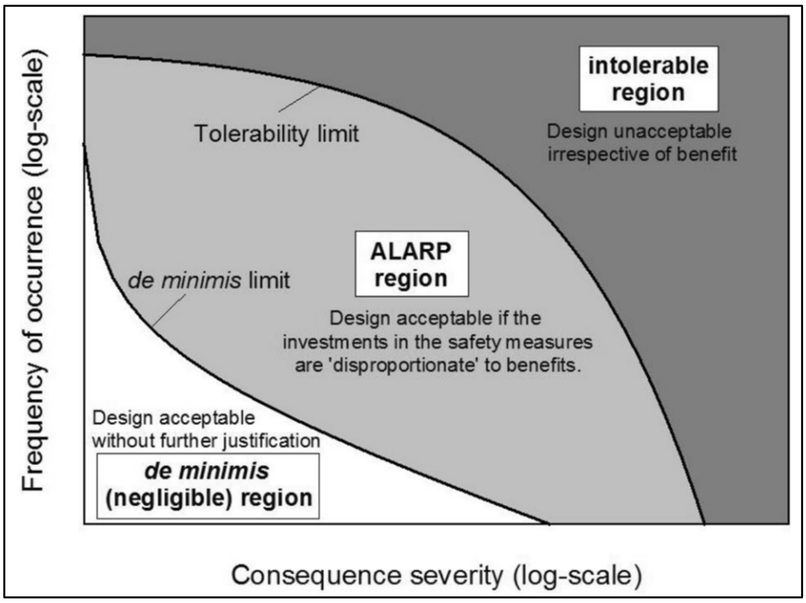

Figure 2 - Levels of risk, and the ALARP region (BSI, 2001)

A risk assessment may determine that an activity is intolerable, but that risk control measures can reduce the risk to make it tolerable (if not broadly acceptable or negligible), either by decreasing the frequency of negative consequences occurring, or decreasing the consequence when the event occurs.

Putting ALARP into practice relies on the definition of 'reasonably practicable', which was developed in the UK and is used internationally. For a particular risk, we consider the effort or resources required to reduce that risk by a given amount. If it can be shown that there is a 'gross disproportion' between the reduction in risk and the effort or resources required, where the reduction is insignificant compared to the effort, the risk is considered to have met the ALARP principle (HSE, 2001). Risks falling in the tolerable region are especially beholden to this idea, as the benefit must be shown to outweigh the risk, and the risk must have been reduced to a level that meets the ALARP principle.

Figure 3 shows the ALARP region with corresponding thresholds which can be used to develop policy responses. It shows that terminology used to determine the levels of risk (and thresholds) and the policy response are vitally important. The following section outlines current terminology used in Aotearoa New Zealand based on the ALARP concept.

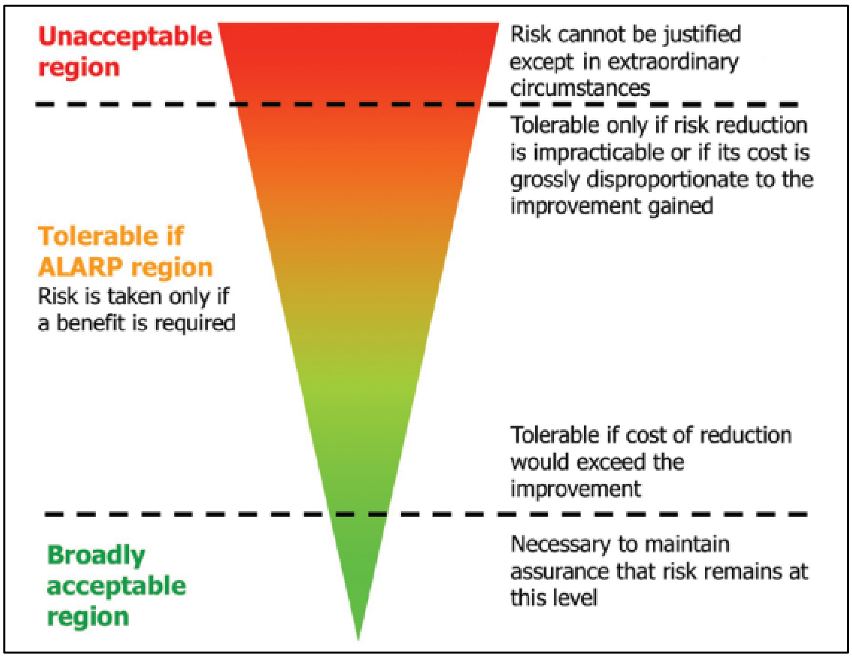

Figure 3 - ALARP concept for tolerability of risk (Risktec, 2018b)

Risk threshold terminology in Aotearoa New Zealand

There is no consistent approach to risk threshold terminology being used in Aotearoa New Zealand, either at a national or sub-national level. Table 2 provides examples of what terms are being used at a national level and shows the variability of terms and their intent.

Table 2 - Risk terminology usage in NZ national policy settings

Who	Terminology used	Description
Department for the Prime Minister and Cabinet (National Risk Approach)	Nationally significant risk	An uncertain, yet conceivable, event or condition that could have serious, long-term effects on New Zealand's security and prosperity, requiring significant government intervention to manage (DPMC, 2022)
WorkSafe	Catastrophic harm	Single incident resulting in more than 5 fatalities (excludes natural disasters) (WorksafeNZ, 2019)
Civil Defence Emergency Management Act 2002	Acceptable	Not defined
	Nationally significant	(a) there is widespread public concern or interest; or (b) there is likely to be significant use of resources; or (c) it is likely that the area of more than 1 Civil Defence Emergency Management Group will be affected; or (d) it affects or is likely to affect or is relevant to New Zealand's international obligations; or (e) it involves or is likely to involve technology, processes, or methods that are new to New Zealand; or (f) it results or is likely to result in or contribute to significant or irreversible changes to the environment (including the global environment)
Resource Management Act 1991	Significant risk (matter of national importance)	Management of significant risk from natural hazards is a matter of national importance, but 'significant' is not defined, nor is the hierarchy clear between nationally important vs significant (i.e., local level significance vs national level).
	NZCPS – high risk (coastal only)	Not defined
Building Act 2004	High seismic risk	Where a building is in an area with a Z factor greater than or equal to 0.3
	Medium seismic risk	Where a building is in an area with a Z factor greater than or equal to 0.15 and less than 0.3
	Low seismic risk	Where a building is in an area with a Z factor less than 0.15

Building Regulations 1992	Importance Level 1	Buildings posing low risk to human life of the environment, or a low economic cost, should the building fail. These are typically small non-habitable buildings, such as sheds, barns, and the like, that are not normally occupied, though they may have occupants from time to time.
	Importance Level 2	Buildings posing normal risk to human life or the environment, or a normal economic cost, should the building fail. These are typical residential, commercial, and industrial buildings.
	Importance Level 3	Buildings of a higher levels of societal benefit or importance, or with high levels of risk-significant factors to building occupants. These buildings have increased performance requirements because they may house large numbers of people, vulnerable populations, or occupants with other risk factors, or fulfil a role of increased importance to the local community, or to society in general.
	Importance Level 4	Buildings that are essential to post-disaster recovery or associated with hazardous facilities.
	Importance Level 5	Buildings whose failure poses catastrophic risk to a large area (e.g., 100 km^2) or a large number of people (e.g., 100,000).
Department of Conservation, from (Taig, 2020a)	Extreme	Adding several-many times comparator risk levels
	High	Adding 100% or more to comparator risk levels (marks boundary within intolerable region between 'stop now' and 'perhaps proceed temporarily subject to corporate review')
	Substantial	Contributing 10s of % to comparator risk levels (marks the upper threshold of tolerability)
	Significant	Contributing one to several % to risk levels from comparators
	Insignificant	Corresponds to the '*de minimis*' level

Waka Kotahi New Zealand Transport Agency[2]	Very high safety risk	Implement a speed management approach focusing on treating the top 10 percent of the network that will result in the greatest reduction in deaths and serious injuries (DSI) Target areas of high collective risk with high DSI reduction measures that achieve a death and serious injury reduction of at least 40%.
	High safety risk – intersections	Collective risk is ≥1.1, estimated using DSI casualty equivalents based on the latest five-year period. This is equivalent to the high or medium-to-high collective risk definition in the High-risk intersections guide. Personal risk is ≥32, estimated using DSI casualty equivalents per 100 million vehicle kilometres travelled. This is based on the latest five-year period and meets the high personal risk definition in the High-risk intersections guide.
	Low safety risk	Any intersection, corridor or route that does not satisfy any of the high or medium safety risk definitions is classified as low safety risk.

At the sub-national level there are also a range of risk terms being used, as shown in Table 3. This is the case even when focusing on one area. For example, despite the common legislative context of the RMA, there are different approaches to risk terms and intent being used for plans under the RMA.

[2] https://www.nzta.govt.nz/planning-and-investment/planning-and-investment-knowledge-base/archive/201821-nltp/assessment-of-activities-by-activity-class/assessment-of-local-road-regional-and-state-highway-improvement-activities/safety-risk-definitions/#safety-risk-definitions

Table 3 - Risk terminology usage in NZ regional policy settings

Who	Terminology used	Description
Bay of Plenty Regional Policy Statement	High natural hazard risk	A level of risk beyond what should be tolerated.
	Medium natural hazard risk	A level of risk that exceeds the Low level but does not meet the criteria for High risk
	Low natural hazard risk	A level of risk generally acceptable. Process for accessing levels of risk is provided.
Otago Regional Policy Statement	Significant	An event whose likelihood is 'Possible' with 'Catastrophic' severity of consequences, or an event that is 'Almost certain' with 'Major' consequences.
	Tolerable	Defined with AIFR* and APR^
	Acceptable	Defined with AIFR and APR
Christchurch District Plan	Unacceptable risk	Defined for slope stability with AIFR
	Acceptable risk	Not defined
	Significant risk	Not defined
	Low risk of danger to public health or safety	Not defined
Auckland Unitary Plan	Unacceptable risk	Not defined
Auckland Regional Policy Statement	Significant risk	Not defined
	Unacceptable risk	Not defined

** AIFR – annual individual fatality risk* *^ APR – annual property risk*

Table 2 and Table 3 demonstrate that there is **varied risk threshold terminology, both nationally and regionally, in Aotearoa New Zealand**. This is demonstrated in Figure 4, which shows where the terms from Table 2 and Table 3 are placed within the ALARP concept, and the associated policy responses.

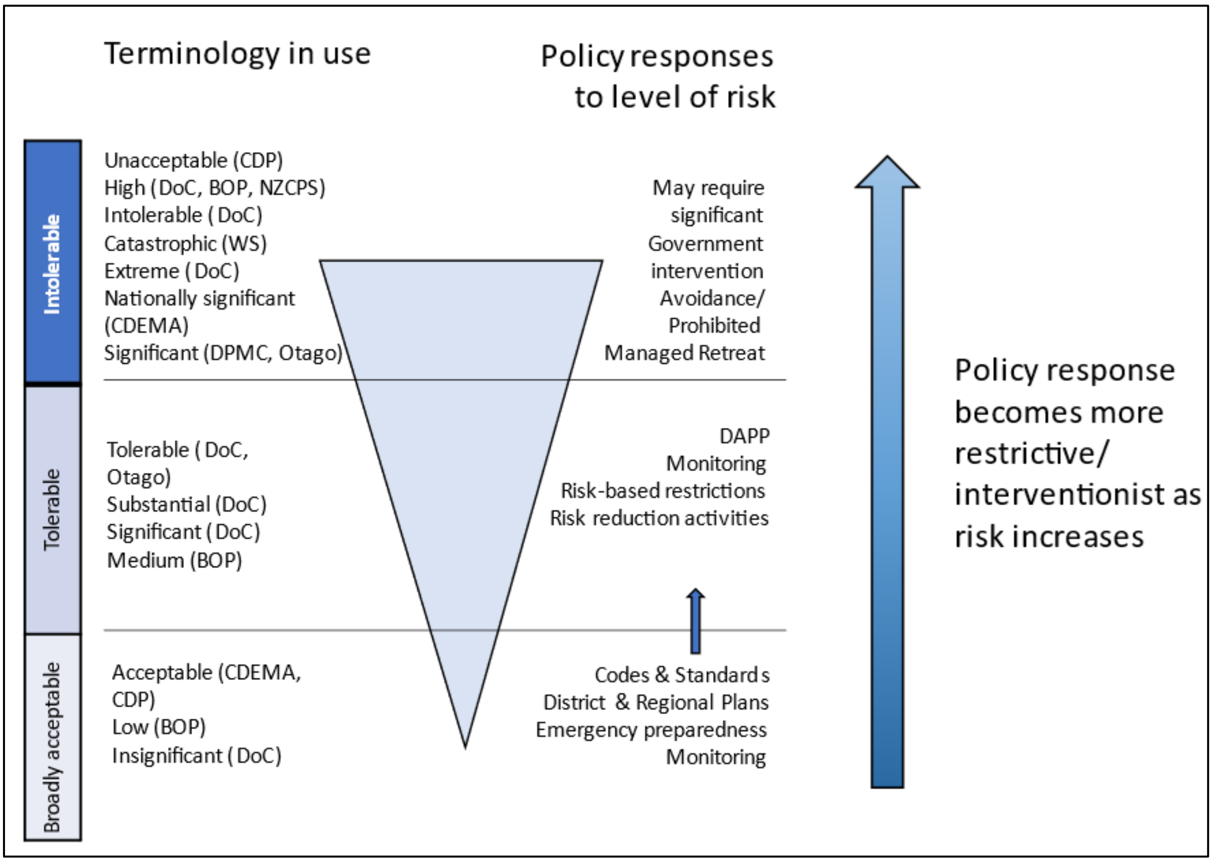

Figure 4 – Examples of terminology in use and policy responses reconciled with levels of risk (Toka Tū Ake EQC, 2022)

Once risk threshold terminology has been agreed, the risk can be measured and evaluated against pre-determined criteria. The following section outlines how risk can be measured.

How to measure risk

If a risk cannot be properly understood or explained, it is difficult—if not impossible—for policymakers, companies, and individuals to make rational choices in response to that risk (Poljanšek et al., 2017), and to implement risk reduction policies.

There are different approaches to measuring, and therefore communicating and considering, risk. They can be varyingly appropriate depending on the context or industry, and the type of activity being considered. Fundamentally, all risk assessments attempt to answer the following questions (Risktec, 2018a):

- What could go wrong?
- How often does it happen?
- How bad are the consequences?
- Is the risk acceptable?

The format of the answers to these questions depends on how we measure the risk. There are three primary methods for measuring levels of risk:

- Quantitative analysis
- Qualitative analysis
- Semi-qualitative analysis

Quantitative analysis

This approach uses numerical, explicit values for both likelihood and consequences. It quantifies risk and provides a finite way of expressing, and especially comparing, risks. Quantitative approaches are associated with complex risk models, coding, and specialist practitioners (Risktec, 2018a).

Quantitative risk analysis is useful for its probabilistic nature in comparing a broad range of scenarios. An example of a quantitative risk assessment is shown in Figure 5, below. The range of consequences presented (horizontal axis) represent the range of scenarios considered, each of different consequence magnitude.

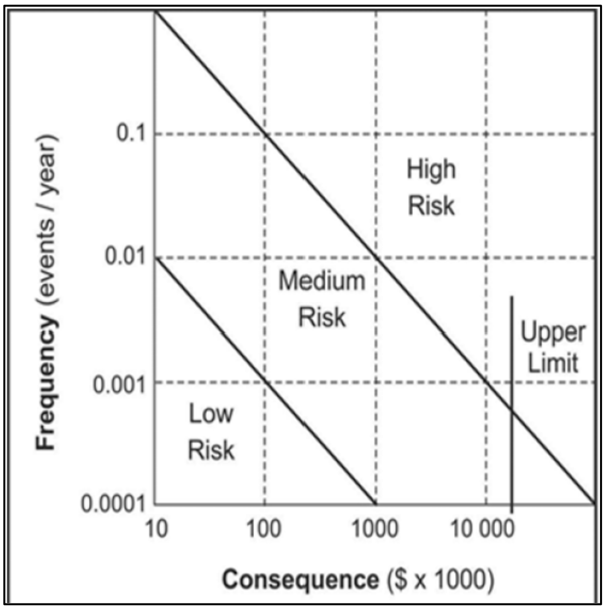

Figure 5 - Quantitative method for estimating risk (SA/SNZ, 2004).

Quantitative analysis reduces ambiguity. An annual risk of 10% is meant to be just that, although limitations in knowledge (epistemic uncertainty) and random variation (aleatoric uncertainty) must be considered. This requires stakeholders to have higher levels of numeracy and comprehension. While this is not an issue for technical professionals, it can be for the public (or policy- and decision-makers who do not have scientific or technical backgrounds). For people who do not understand the context, quantitative risk analysis can seem more certain than it is because it presents a finite number. It is important for quantitative methods to also communicate their underlying assumptions and uncertainty (Risktec, 2018a).

On the other hand, describing the risk qualitatively as 'low' or 'tolerable' is unclear and can mean different things to different stakeholders. Stakeholders also tend to assume that risks are higher if the risk information is not presented in numbers, but with only qualitative descriptors (Fischhoff, 2011). This means quantitative analysis may be more effective for stakeholders with high numeracy, but qualitative analysis may be more appropriate for others, despite its ambiguity (Fischhoff, 2011).

Qualitative analysis

This approach uses words to describe the magnitude of potential consequences and the likelihood that the event will occur. Qualitative analysis is considered less rigorous than quantitative or semi-qualitative analysis (Poljanšek et al., 2017) because it often avoids numerical calculation or modelling. An example of this is a risk matrix, as shown in Table 4 below.

Table 4 - Example of a qualitative risk matrix to determine level of risk

	Consequences		
Likelihood	Minor	Moderate	Major
Likely	Medium level of risk	High level of risk	High level of risk
Possible	Low level of risk	Medium level of risk	High level of risk
Unlikely	Low level of risk	Low level of risk	Medium level of risk

A high level of risk can be described as 'intolerable', a medium level of risk 'tolerable', and a low level of risk 'acceptable'. Examples of qualitative consequence descriptors is provided in Table 5.

Table 5 - Associated social and policy responses to various levels of risk (Kilvington & Saunders, 2015)

Level of risk	Definition	Response
Broadly acceptable risk	Risk that people are prepared to live with knowing that no additional measures will be taken to reduce it.	Everyday response: Part of daily life – these things happen. Policy response: All future activities should fit within this threshold.
Tolerable risk	Risk that people are prepared to endure because of the benefits of the activity but expect measures to taken to reduce it.	Everyday response: It is awful, but possible for a community to recover from it in time. Policy response: Measures should be taken to reduce the risk for existing activities that fit within this threshold.
Unacceptable risk	Risk that people are not prepared to endure regardless of the benefits of the activity.	Everyday response: No way! The risk is so great that it cannot be justified. Policy response: Activities will not be permitted above this threshold except in limited, unpreventable circumstances (for example, ports by their nature may unavoidably be located in high-risk areas).

Qualitative analysis allows personal or individual prioritisation of risks and consequences, but this inherently introduces some form of bias, which makes qualitative analysis subjective (compared to quantitative, which is considered objective) (Safran, 2022). Perhaps its greatest strength is the ability to add context to a risk. Again, using an example with an annual risk of 10%, a quantitative level of risk has little meaning on its own. Context is needed to convey the meaning behind a 10% risk, either with risk comparators (for example, comparing the 10% to other clear tangible levels of risk) or with qualitative descriptors of 'more' or 'less severe'.

Because qualitative analysis can be subjective, it may need to be updated over time as different people reconsider the risks, or the context changes. New descriptors may need to be added to reflect changing risk appetites, or the interpretations of the same descriptors may change based on who is using them.

Semi-qualitative analysis

This approach uses a combination of words and numbers. Semi-qualitative analysis uses quantitative analysis to determine numerical risks but presents the information in formats similar to qualitative measures. It categorises risks by comparative scores, not explicit probabilities. It is considered more rigorous than purely qualitative approaches, but less so than quantitative approaches (Poljanšek et al., 2017). An example is shown in Figure 6, below.

Frequency (events / year)	**V.Low** (100	**Low** 300	**Medium** 1000	**High** 3000)
0.1	10	30	100	300
0.01	1	3	10	30
0.001	0.1	0.3	1	3
0.0001	0.01	0.03	0.1	0.3

Consequence ($ x 1000)

Figure 6 - Semi-qualitative method for estimating risk (SA/SNZ, 2004).

Risk to what

Managing risk requires first considering what is at risk. This means considering the potential effect on the things we value, like risk to life, property, infrastructure, and financial risk, each of which are discussed below. While there is no formal national direction on what risk to manage, other sources provide guidance.

The UNDRR Sendai Framework for Disaster Risk Reduction (SFDRR) outlines the societal effects to consider in a risk analysis. These are impacts on human health and safety, the economy, the environment, the social and political stability, cultural heritage, and education, as well as negative consequences for the Sustainable Development Goals (SDGs) (UNISDR, 2017). Aotearoa New Zealand is a signatory of the Sendai Framework, and these impact areas are consistent with national direction within Aotearoa New Zealand's legislation, discussed below.

NZ legislative direction

A number of Aotearoa New Zealand statutes provide direction on what could be considered when determining risk thresholds. When comparing the RMA, CDEM Act, Building Act 2004 and LGA, common themes include social, economic, and cultural wellbeing; and health and safety, with the common aim of promoting sustainable management and development (see Table 6 below).

Table 6 - Relevant NZ statutes on risk tolerance (emphasis added)

Statute	Purpose
Resource Management Act 1991 (RMA)	Promote the **sustainable management** of natural and physical resources… managing the use, development, and protection of natural and physical resources in a way, or at a rate, which enables people and communities to provide for their **social, economic, and cultural well-being** and for their **health and safety**
Civil Defence Emergency Management Act 2002 (CDEM)	Improve and promote the sustainable management of hazards in a way that contributes to the social, economic, cultural, and environmental well-being and safety of the public and also to the protection of property
Building Act 2004	People who use buildings can do so **safely and without endangering their health**…Buildings have attributes that contribute appropriately to the **health, physical independence, and well-being** of the people who use them; buildings are designed, constructed, and able to be used in ways that promote **sustainable development**
Local Government Act 2002 (LGA)	Provides for local authorities to play a broad role in promoting the **social, economic, environmental, and cultural well-being** of their communities, taking a **sustainable development** approach.
Health & Safety at Work Act 2015	Workers and other persons should be given the highest level of protection against harm to their **health, safety, and welfare** from hazards and risks arising from work or from specified types of plant as is reasonably practicable.

The consistent themes in the purpose statements, which are also consistent with the Sendai Framework, give clear direction on what to consider when developing risk metrics.

Risk to life

Risk to life is the focus of many risk assessments. The annual individual fatality risk (AIFR) is a quantitative loss-of-life risk measure. AIFR refers to the probability of a fatality for an individual at a specific site in any given year (Gunnel, 2019). The Australian Geomechanics Society guidelines to inform risk zoning[3] (AGS, 2007) have recommended using a quantifiable loss-of-life metric since 2007. In Aotearoa New Zealand, there were no loss-of-life criteria for natural hazard risk assessments before 2012 (Taig, Massey, & Webb, 2012). However, the use of such criteria has increased over the last decade following responses to the Canterbury Earthquake Sequence, Matatā debris flow, and other events.

Determining AIFR for natural hazards involves considering the probability of an event, the exposure of individuals at risk, and their vulnerability if they are affected (Corominas, et al., 2014). A logarithmic scale is used (see Table 7 example, below) for comparison because in a particular year, the risk associated with natural hazards is generally much lower than the likelihood of an individual being killed by another hazard (e.g., road incident or disease) (Taig, Massey, & Webb, 2012).

Table 7 - Different ways of expressing risk probabilities (Clarke et al., 2021)

Probability: 1 in… (per year)	Exponential expression	Percentage (annual exceedance probability)	Lifetime (based on 80-year life expectancy)
100	10^{-2}	0.01 or 1%	80%
1,000	10^{-3}	0.001 or 0.1%	8%
10,000	10^{-4}	0.0001 or 0.01%	0.8%
100,000	10^{-5}	0.00001 or 0.001%	0.08%
1,000,000	10^{-6}	0.000001 or 0.0001%	0.008%

A 1 in 10,000 annualised chance of death, or an AIFR of 10^{-4}, is widely considered to be a tolerable level of risk, as reflected in Table 8 which is taken from the Australian Geomechanics Society (2007) guideline.

[3] The Australian Geomechanics Society methodology is well recognised as best practice in New Zealand and has been used in many risk assessments across the country.

Table 8 - Recommended descriptors for risk zoning using life loss criteria (AGS, 2007).

Annual probability of death of the person most at risk in the zone	Risk zoning descriptors
> 10^{-3} / annum	Very High
10^{-4} to 10^{-3} / annum	High
10^{-5} to 10^{-4} / annum	Moderate
10^{-6} to 10^{-5} / annum	Low
< 10^{-6} / annum	Very Low

Loss of life can be assessed at either an individual or societal scale. A limit to individual risk can also be used to codify a minimal safety level to 'society', or every person living with a risk (for example, behind a primary flood defence). The Netherlands proposed an individual risk limit of 10^{-6} per year (including the effectiveness of evacuation) for flood safety of people living behind primary flood defences. FN-curves show the probability distribution of the number of fatalities and can be used to evaluate fatality risks from a societal perspective (Jonkman, Jongeian, & Maaskant, 2011). The section on Individual vs societal risks, below, further discusses this relationship.

Risk to property

Property is an example of an asset considered in risk assessments. Property, including land and constructed assets, is where most human activity happens. Effects on property include damage, the associated losses or costs of repair, and loss of use—whether that applies to service provided in critical or sensitive facilities (such as emergency response facilities), or to the business operations.

Property risk can be expressed quantitatively as annual property risk (APR), which is the annual probability of total property loss due to some hazard (Beca, 2020). It involves considering the probability of the hazard event, the exposure of the property in such an event, and the vulnerability of the property to the hazard. It can then be combined with the monetary value of the property to represent risk of total property loss. This makes APR another expression of financial risk (discussed below).

The Otago Regional Policy Statement (RPS) (ORC, 2021a) takes this approach, where both the AIFR and APR are the selected risk metrics because they capture the likely consequences of a wide range of natural hazards. For example, some natural hazard events may not cause fatalities, but may result in widespread damage to property, while other natural hazard events have a high capacity to cause fatalities. The Otago RPS includes different risk thresholds for areas of new development and areas of existing development. It applies a 'first-past-the-post' principle to re-categorising risk for the AIFR and APR to ensure decisions are based on the greatest risk present between the two metrics:

(a) for areas of new development where the greatest AIFR or APR is:

(i) less than 1×10^{-6} per year, the risk is re-categorised as acceptable,

(ii) between 1×10^{-6} and 1×10^{-5} per year, the risk is re-categorised as tolerable, or

(iii) greater than 1×10^{-5} per year, the risk is re-categorised as significant.

(b) for areas with existing development, where the greatest AIFR or APR is:

(i) less than 1×10^{-5} per year, the risk is re-categorised as acceptable,

(ii) between 1×10^{-5} and 1×10^{-4} per year, the risk is re-categorised as tolerable, or

(iii) greater than 1×10^{-4} per year, the risk is re-categorised as significant.

This shows how both life safety and property risk for existing and new development have been used as metrics in a policy setting. The *Section 32 Evaluation Report* (ORC, 2021b) supporting the Otago RPS explains that a consultation process with communities, stakeholders, and partners about risk levels thresholds is required to understand what the community's tolerance to risk is.

Under the RMA, when preparing or amending a regional and/or district plans, local authorities must undertake a consultation process with communities, stakeholders, and partners about risk level thresholds. Using the information gathered through the consultation process, local authorities in Otago must also develop a risk table in accordance with those outlined in the RPS at a district or community level.

Beyond APR and considering property from a purely monetary, capital perspective, the nature of some properties or buildings means local authorities need to consider indirect effects. Buildings that provide certain services (like healthcare or public services) may carry low APR because of low property values or low expected damage levels. However, an asset-driven risk approach does not account for the effects on the people who rely on the services provided. Nuth et al. (2021) expand on balancing life safety costs with community, or social, costs for Aotearoa New Zealand councils responsible for portfolios that include earthquake-prone buildings. Decisions on property and building risk should account for these qualitative values as well.

Risk to infrastructure

Risk to infrastructure is commonly used when assessing natural hazard risks, because having a resilient infrastructure network is essential for a resilient community. If infrastructure fails, it can severely delay the community's response and recovery. Many regional lifelines projects have been undertaken and continue to guide lifeline utility vulnerability assessments and risk mitigation programmes. These typically assess criticality, exposure, vulnerability, restoration, and mitigation, as shown in Figure 7.

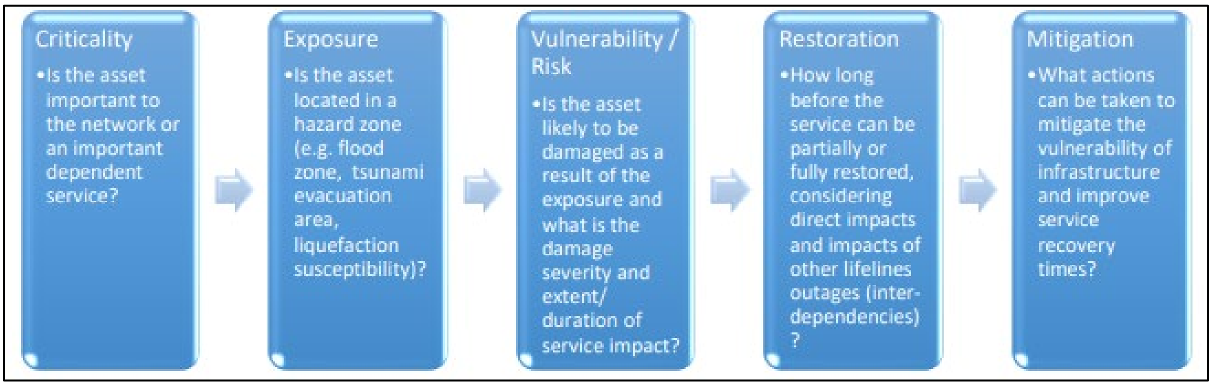

Figure 7 - Overview of the typical Vulnerability Assessment Process for infrastructure (NZLC, 2020, p. 8)

The NZ Lifelines Council encourages a consistent approach to defining critical assets for regional lifelines projects, illustrated in Figure 8. This provides a consistent language within the infrastructure lifelines sector and makes it possible to compare and prioritise infrastructure criticality nationally. The methodology has been used in all regional Lifelines group projects in the past decade (sometimes in a modified form). The criticality rating depends on both the numbers of customers affected and the criticality of those customers (for example, other lifelines or hospitals) to show the overall consequence of the asset failing (NZLC, 2020, p. 13).

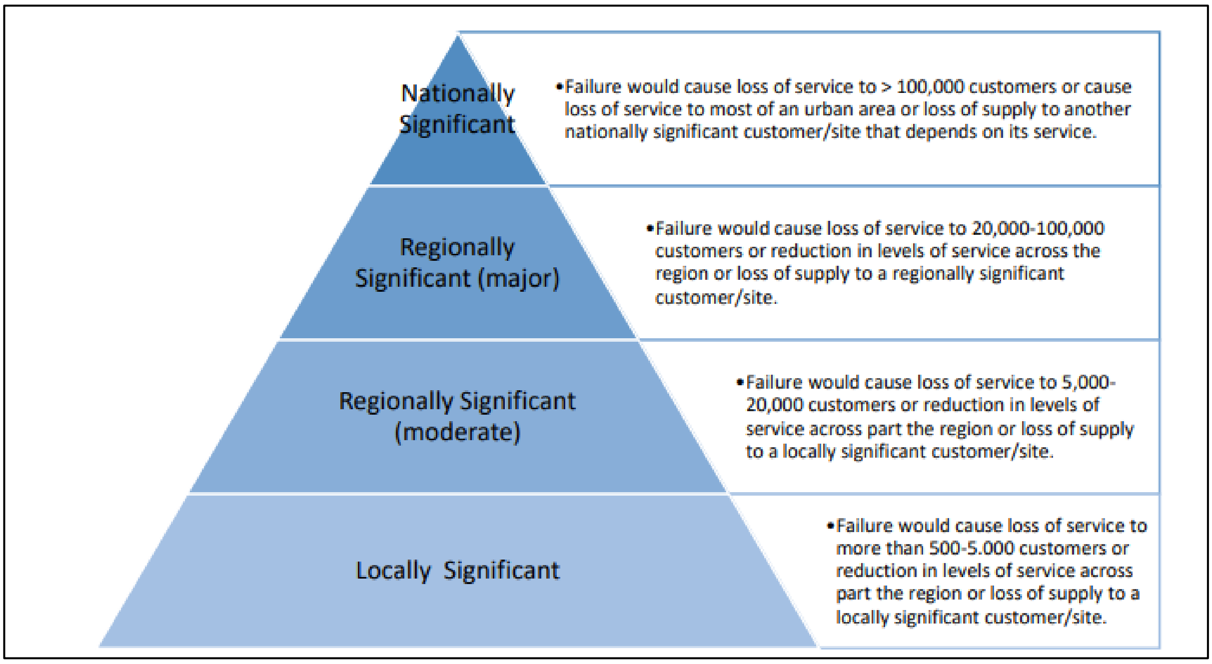

Figure 8 - Assessing Infrastructure Asset Criticality (NZLC, 2020, p. 14)

The assessment criteria outlined in Figure 7 and Figure 8 is applied in the New Zealand Critical Lifelines Infrastructure National Vulnerability Assessment (2020), but regions and organisations have modified the thresholds for 'regionally' and 'locally' significant – reflecting the regional context.

An approach similar to that shown in Figure 7 and Figure 8 could be used to inform the development of a risk metric for infrastructure. The Treasury has also offered a metric for assessing national level infrastructure risk, discussed in multi-criteria risk metrics, below.

Financial risk

Measuring the costs of disasters, either as part of a forward-looking assessment or when estimating damage and losses after a disaster, requires an estimate direct and indirect financial and economic effects. Methodologies, like OECD (2015), bring consistency and accuracy to this process, and have been developed to support governments in the ex-post valuation of damages and economic losses and enable governments to assess needs after a disaster. This allows them to distribute resources efficiently in the recovery phase by including estimates of:

- Direct damages: The replacement value of totally or partially destroyed physical assets (like infrastructure, buildings, installations, machinery and equipment, transportation vehicles, damage to farmland, irrigation works and reservoirs).
- Indirect losses: Losses in the flows of the economy that happen because productive assets are temporarily unavailable or damaged (like losses caused by lost industrial production, decreased agricultural yield due to flooding or prolonged droughts, or increased transportation costs).
- Macroeconomic effects: The resulting effect on post-disaster macroeconomic performance (for example, economic growth, balance of payments, fiscal position).

The insurance industry largely uses financial effects to quantify risk. Losses are often averaged over many hazards, markets, and considerable time frames, then they are annualised, resulting in expected annual losses (EAL) or average annual losses (AAL). Like AIFR, this provides an easily understood metric (money) and can be expressed as an explicit number rather than a qualitative scale. Economic losses can also be combined and expressed as a percentage of a country's Gross Domestic Product (GDP) to communicate relative scale of the event.

A fatality, for example one associated with AIFR described above, can also be quantified by the value of statistical life (VOSL), and so expressed as an economic impact to society as well. The VOSL is "thought to express all the tangible and intangible values of a life lost or a life saved" (BERL, 2007). In Aotearoa New Zealand, the VOSL was first estimated in 1991 at $2 million (Miller & Guria, 1991) and used to determine investment to reduce the risk of premature death from road crashes. However, Guria (2010) notes this figure was only applicable to the transport sector in Aotearoa New Zealand and could not simply be applied to all kinds of risks or sectors: "The VOSL is an estimate based on what people were prepared to pay for a reduction of a reasonably specific risk. And there is evidence that what people are prepared to pay for a risk reduction may differ by the type of risk." Treasury's most recent (2022) VOSL figures put the value of the average New Zealander at approximately $5.2 million (adjusted to 2023 values), although this still seems to be based on data from the transport sector.

Metrics like VOSL and annual property risk (APR) show that other risks can be expressed in financial terms. Effects on infrastructure, especially the resulting disruption of services, can also be quantified financially. Financial risk is a useful way to describe risk because it is so versatile in translating various kinds of effects into a concise, easily understandable metric that can also be converted between countries and currencies.

It is important for governments to quantify financial vulnerabilities when they are 1) evaluating the use of risk financing tools to mitigate the fiscal costs of disasters or secure post-event liquidity, or 2) considering major public investment projects to reduce disaster risk.

For the insurance sector, it is critical to quantify risk for sound disaster risk underwriting. Appendix A6 Disaster risk financing further explores mitigating financial losses through disaster risk financing.

Multi-criteria risk metrics

Multi-criteria impact metrics have one or more impact criteria, so the effects can be estimated in a transparent and comparable way for each risk. From UNISDR (2017), there are several ways to operationalise the criteria:

- Quantitative indicators: This can be a number (such as fatalities) or amount (costs), but it can also be a combination of two quantitative dimensions, for example number and duration (in cases of displacement or lack of essential items).
- Qualitative indicators: This can be any kind of single indicator or combination of multiple indicators that predict a certain level of impact.
- Qualitative impact level descriptions: If it is difficult or impossible to identify measurable indicators, each of the impact levels of a criterion could be operationalised by a qualitative description of 'expected consequences. For example, a description of tangible collective behaviour for different levels of social unrest.

Each impact criterion needs to be operationalised in the same number of impact levels (for example five levels, from 'insignificant' to 'catastrophic'). There must be consistency across criteria, to ensure scales or levels of impacts are proportional across each criterion. So, relatively minor impacts in one criterion must correlate with minor impacts across the other criteria. Because the different societal impacts are not inherently interchangeable or comparable, defining this consistency requires both expert elicitation and political decision. An example is provided in Table 9, below.

Data for analysing impact (and likelihood) levels can be drawn from risk analyses of sectors and single hazards. If those are not available, the expert elicitation of the scenarios should provide the required information on the impact criteria/indicators.

Like the criteria shown in Table 9, the NZ Treasury in 2019 produced a multi-criteria impact framework for infrastructure. The purpose was to identify government's most critical assets and the NZLC and Treasury agreed to collaborate on the review. Treasury's (draft) framework (Table 10, below) was developed following research on many criticality frameworks used by other countries, regions, sectors, and organisations. It provides a common framework to measure relative levels of criticality for all national assets. It is not intended to replace organisational risk frameworks (which are scaled to fit their organisation).

Table 9 - Example of multi-criteria analysis measures (UNISDR, 2017)

Societal value	Societal impact criteria
Human impact (health and safety)	• Fatalities • Severely injured or ill people • Permanently displaced people • People with lack of basic necessities
Economic impact	• Fatalities • Severely injured or ill people • Permanently displaced people • People with lack of basic necessities
Environmental impact	• Disruption of ecosystems • Environmental pollution • Loss of ecological value
Social and political impact	• Public outrage and anxiety/social-psychological impact • Disruption of daily life • Disruption of the education system • Encroachment of the territory • Infringement of the international position • Violation of the democratic system • Impact on public order and safety • Loss of social cohesion
Impact on cultural heritage	• Loss of cultural heritage and value

This approach also parallels the NZ Treasury's Higher Living Standards Framework (Treasury, 2021). The framework combines the consequences to human life, social and cultural structures and norms, governance, natural environment, economic impact, and physical asset value. These consequences are aligned with those in the legislation (refer above), which are health and safety, social, cultural, economic, and environmental. Five magnitudes of consequence are provided, from insignificant to extreme. Table 10 provides relatively clear direction from the Treasury on qualitative and quantitative criteria that can be used to determine a level risk. The next step would be to incorporate likelihood and determine the risk thresholds.

Saunders, Beban & Kilvington (2013) took a similar approach for land use planning purposes. They accounted for legislative themes of social, cultural, economic and health and safety, and infrastructure needed to ensure these areas continue to function (see Table 11). Table 10 and Table 11 use different metrics, for two different purposes. When combined with likelihood, the resulting risk-based metric provides a basis for determining risk thresholds for policy and resource consent activities. Versions of this table have been used in the Bay of Plenty and Otago Regional Policy Statements, and in numerous district plans.

Table 10 - Combined consequence table from NZ Treasury Draft Criticality Model (NZLC, 2020, p. 16)

Consequences		Insignificant	Minor	Moderate	Major	Extreme
	Scope	1	2	3	4	5
Human (life)	Human health and wellbeing, physical and mental. Includes impacts of illness, injury, income, skills, knowledge and the things that enable people to engage in society.	Mild impacts and inconvenience	Local/moderate illness or injury with no deaths, or serious hardship for <1000 people	Regional/serious illness or injury, 1 death likely, or serious hardship for >1000 people	National/serious illness or injury, up to 10 deaths, serious hardship for >10,000 people	more than 10 deaths, or serious hardship for >100,000 people
Social (&cultural)	Social and cultural structures and norms in NZ, law and order, cultural identity, communities, and community, social, and cultural facilities	Local public issue and sense of frustration or disadvantage	Regional public issue, loss of community facilities or impacts to social or cultural practices, sense of injustice within communities.	National sense of injustice, damage to many communities, social or cultural values challenged, public protests	Damage to social or cultural structures or values for up to 1 year, serious protests/disruptions, or loss of high value heritage	Long-term or permanent loss of social structures or key cultural values/identity. Civil disobedience and extended disruptions.
Governance (political)	Trust in government or management, maintaining credibility and a mandate to lead and/or continue to supply services. Includes international reputation.	Local issue (single region), stakeholder frustration	Issue for <1 month, with embarrassment for Govt or asset manager and some loss of confidence	Issue for <3 months, with loss of confidence in responsible ministers/officials/executives	Issue for >3 months, with loss of confidence and trust in Govt or organisation (asset manager)	long-term loss of trust in Govt or organistion (reputation), impaired ability to govern
Environment (natural env.)	All aspects of the natural environment to support NZ and the planet (biodiversity) and human wellbeing. Includes land, water, plants, animals, and other natural resources.	Minor, very localised impact <1ha, no residual effects	local area impact, recoverable, effects last <3 months	Local/regional impact, recoverable, effects last < 1 year	Regional impact, effects last > 1 year, some long-term residual impacts	Regional impact > 1 year, or long-term or permanent loss of ecosystem, species, or a natural resource
Economic (#people)	The economic impact to NZ (GDP). This is broadly indicated by the number of people impacted directly and indirectly, and may include customers, customers of impacted businesses, suppliers, and others.	Proxy= Total people impact, direct and indirect. # people <500	# people > 500	# people > 5000	# people > 50,000	# people > 500,000
Physical (asset value)	The value of the physical (or intangible) asset being assessed. An estimate of the <u>replacement</u> value of the asset (an indicator of impact to the asset owner).	Proxy= Total replacement value of asset. asset < $10m	asset > $10m	asset > $100m	asset > $1B	asset > $10B

Table 11 - Consequence matrix for risk-based planning (Saunders, Beban, & Kilvington, 2013)

Severity of Impact	Built				Economic	Health &Safety
	Social/Cultural	Buildings	Critical Buildings	Lifelines		
Catastrophic (V)	≥25% of buildings of social/cultural significance within hazard zone have functionality compromised	≥50% of affected buildings within hazard zone have functionality compromised	≥25% of critical facilities within hazard zone have functionality compromised	Out of service for > 1 month (affecting ≥20% of the town/city population) OR out of service for > 6 months (affecting < 20% of the town/city population)	> 10% of regional GDP	> 101 dead and/or > 1001 inj.
Major (IV)	11-24% of buildings of social/cultural significance within hazard zone have functionality compromised	21-49% of buildings within hazard zone have functionality compromised	11-24% of buildings within hazard zone have functionality compromised	Out of service for 1 week – 1 month (affecting ≥20% of the town/city population) OR out of service for 6 weeks to 6 months (affecting < 20% of the town/city population)	1-9.99% of regional GDP	11 – 100 dead and/or 101 – 1000 injured
Moderate (III)	6-10% of buildings of social/cultural significance within hazard zone have functionality compromised	11-20% of buildings within hazard zone have functionality compromised	6-10% of buildings within hazard zone have functionality compromised	Out of service for 1 day to 1 week (affecting ≥20% of the town/city population) OR out of service for 1 week to 6 weeks (affecting < 20% of the town/city population)	0.1-0.99% of regional GDP	2 – 10 dead and/or 11 – 100 injured
Minor (II)	1-5% of buildings of social/cultural significance within hazard zone have functionality compromised	2-10% of buildings within hazard zone have functionality compromised	1-5% of buildings within hazard zone have functionality compromised	Out of service for 2 hours to 1 day (affecting ≥20% of the town/city population) OR out of service for 1 day to 1 week (affecting < 20% of the town/city population)	0.01-0.09 % of regional GDP	<= 1 dead and/or 1 – 10 injured
Insignificant (I)	No buildings of social/cultural significance within hazard zone have functionality compromised	< 1% of affected buildings within hazard zone have functionality compromised	No damage within hazard zone, fully functional	Out of service for up to 2 hours (affecting ≥20% of the town/city population) OR out of service for up to 1 day (affecting < 20% of the town/city population)	<0.01% of regional GDP	No dead No injured

Risk to whom

Individual vs societal risks

Risks can be assessed at an individual level, or at a wider societal level. Jonkman et al. (2011) state that **individual risk** concerns the annual probability of death of a person, whereas **societal risk** concerns the probability of an event with many fatalities.

Muhlbauer (2004) describes individual and societal risk as:

> *"Individual risk provides an estimate for the risk to an individual at a specific location for a specified period of time. In many applications, individual risk is equivalent to the risk to 'one or more individuals.' The individual risk is insensitive to the number of individuals present, but the time of exposure for an individual can be considered.*
>
> *Societal risk is usually taken to mean the relationship between the frequency and number of individuals that could suffer a specified harm—for instance, the annual risk of death of a large number of people in one incident. It does consider the number of individuals exposed as well as their times of exposure."*

Individual risk does not completely describe situations where a single accident could kill or injure large numbers of people. For example, in the UK "… decision makers are aware that there is a big public reaction when a train crash kills a number of people, while the fact that a greater number die on … roads every day goes largely unnoticed" (AEF, 2009).

Because societal risk accounts for many possible scenarios (such as various fatality count scenarios), F-N curves are often used to display risks, which plots the cumulative frequency of events that can cause N+ number of fatalities versus number of fatalities. An example is shown in Figure 9, below.

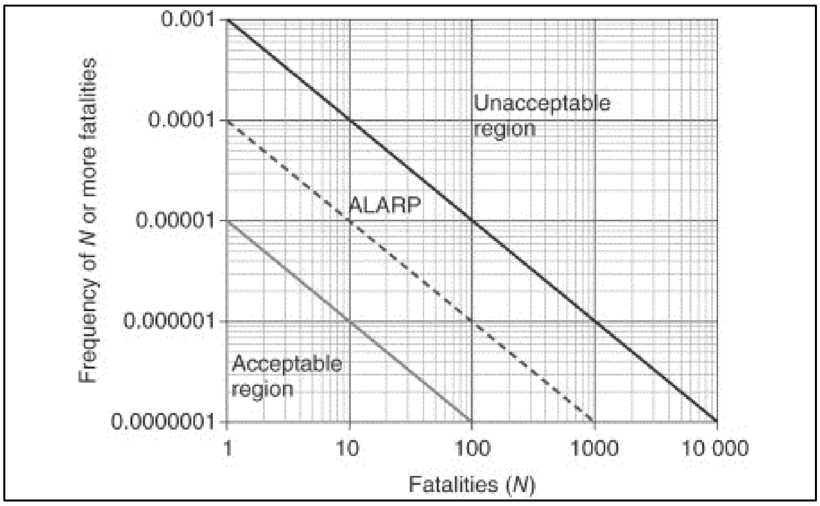

Figure 9 - Example of a F-N curve (Tesfamariam & Goda, 2013)

Often both individual and societal risks are assessed. The internationally accepted HSE (2001) approach states that “both the level of individual risks and the societal concerns engendered by the activity or process must be taken into account when deciding whether a risk is acceptable, tolerable or broadly acceptable” (p3) and “hazards that give rise to individual risks also give rise to societal concerns and the latter often play a far greater role in deciding whether risk is unacceptable or not” (p46).

HSE (2009) generally advise against a proposed development that would bring a significant number of people into an area where their individual risk levels would be significant or substantial compared with other involuntary risks they are exposed to in everyday life. Where the risks are lower than this, HSE generally does not advise against the proposed development. The criteria HSE use include an implicit societal risk consideration for each individual development, where the number of people likely to be at the development is considered in determining ‘sensitivity level’. Individual and societal risks are typically represented through loss-of-life metrics, as discussed above.

Options for using both individual and societal risk

Both the level of individual and societal concerns must be considered when deciding whether a risk is unacceptable, tolerable, or broadly acceptable (HSE, 2001).

Within the context of road safety in Aotearoa New Zealand, both collective (societal) and personal (individual) risks are measured. Collective risk refers to a measure of the total number of fatal and serious injury crashes per kilometre over a section of road. Personal risk refers to a measure of the danger to each individual using the state highway being assessed. Both are represented as equations (KiwiRAP, n.d.).

Within the context of Dutch flood safety policy, Jonkman et al (2011) propose three options for how individual and societal risk could together contribute to flood safety policy. These become more stringent as they proceed:

1. Use individual and societal risk for agenda setting and/or policy evaluation purposes. Policymakers consider (past or potential changes in) levels of individual and societal risk when making policy choices. There is no formal rule stipulating action when some predefined level of individual or societal risk is exceeded.
2. Define criteria or reference values for evaluating individual or societal risks but allow exceedances when there are strong reasons to do so. Decision rules that seem reasonable in some cases might lead to grossly disproportionate outcomes in others. Allowing for flexibility can reduce the unintended social cost of rules and regulations, but it can dramatically increase transaction cost (the cost of decision-making).
3. The Government lays down legal limits to individual and societal risks. These limits would then have a similar status to the exceedance probabilities that are currently outlined in [the Dutch Flood Defence Act]. When prevention would be the basis for the flood risk management policy, the Government could also define maximum flood probabilities, based on considerations related to individual and societal risks.

A similar approach for Aotearoa New Zealand could be investigated further.

Risk perception

Much of this Discussion Paper focuses on actual, real risk – a level of risk that has been methodically determined, using either quantitative or qualitative means, and most closely conveys the true level of risk.

'Perceived' vs 'actual' risk

Perceived risk reflects the subjective judgements and interpretations made about the characteristics or severity of a risk (Paek & Hove, 2017). Perceived risks are explicitly different from real risks (Godovykh, et al., 2021). Because 'risk' varies drastically depending on context (What is risk?, above), so can the factors that contribute to conceptions of risk. Slovic (2016) found that public perception of risk incorporated considerations such as "uncertainty, dread, catastrophic potential, controllability, equity, risk to future generations, and so forth", whereas 'expert' perceptions of risk homed in on 'probability of harm or expected mortality'.

Godovykh, et al., (2021) found that perceived risk can differ from real risk because of a wide range of factors, including:

- Individual factors – gender, age, cultural characteristics; personality traits
- Affective factors – emotions, feelings, mood
- Contextual factors – framing of risk information (e.g., 'the glass is half full' vs 'half empty') and availability of alternative information sources
- Cognitive factors – anchoring, adjustment, social influence, status quo bias, perceived control

Other cognitive behavioural biases (Meyer & Kunreuther, 2017) include:

- myopia – a tendency to focus on overly short future time horizons when appraising immediate costs and the potential benefits of protective investments
- amnesia – a tendency to forget too quickly the lessons of past disasters
- optimism – a tendency to underestimate the likelihood that losses will occur from future hazards
- inertia – a tendency to maintain the status quo or adopt a default option when there is uncertainty about the potential benefits of investing in alternative protective measures
- simplification – a tendency to selectively attend to only a subset of the relevant facts to consider when making choices involving risk
- herding – a tendency to base choices on the observed actions of others

The broad range and number of factors can interact with and compound each other, making risk perception complex to anticipate and account for (Godovykh, et al., 2021). Amnesia bias also suggests that risk perception is dynamic and can vary over time. Risk appetite is highly variable between individuals and with time. It is influenced by personal preferences as well as the effect of past events and how long ago they occurred (Ball, et al., 2022). Changes in risk perception may be most dramatic when comparing attitudes before and after an event. It is well known that trends in preparedness tend to peak soon after major events before declining over time (Johnston, et al., 2013).

Many of the factors described above—especially cognitive behavioural biases—seem to reduce perceived level of risk compared to actual risk. However, a 'social amplification of risk' is also possible (Kasperson, et al., 1988), where "information processes, institutional structures, social-group behaviour, and individual responses shape the social experience of risk, thereby contributing to risk consequences". Kasperson et al. (1988) gives several examples where perceptions of, and social response to, some risks were greatly influenced by recent events shown in the media. This led to a disproportionate aversion to specific risks compared to other, potentially worse risks that received less public interest.

For example, nuclear accidents and ethylene dibromide exposure via food or water received significant media exposure in the 1970s and 1980s in the US, and perceived risk from these increased accordingly. On the other hand, driving without seatbelts, and ethylene dibromide exposure via leaded gasoline and vehicle emissions—both of which were arguably greater risks to society—received relatively little media attention and so risk perceptions and behaviour followed.

Effective risk communication that prompts people to reduce their risk must consider different personalities, biases, worldviews and fear factors, and present information in a way that helps them to receive the message.

Importance for decisionmakers and risk communication

"Despite the inaccuracy of public perceptions…removing the public from the hazard-management process [is] not feasible in a democratic society" (Slovic, 2016). So, it is vital for decision-makers and people communicating risk to understand how risk perceptions can affect behaviour and choices.

Risk perception may ultimately be more important in affecting behaviour and choices than actual risk (Ball, et al., 2022). Similarly, "understanding how people view risk is often as important as understanding the risk itself" (Taig, 2011). Human behaviour is not solely based on rational assessment of facts – it is heavily influenced by a complex range of individual and social influences with sometimes surprising effects, which can make the resulting choices seem irrational (Eiser, et al., 2012).

People generally subconsciously take a stance that removes or lessens the stress and fear in their everyday lives (Ball, et al., 2022). Sandman (1989) describes a state of 'low level of outrage' where people may resist information that encourages action that inconveniences them. People may dismiss the information as unimportant, question or disbelieve it, or distrust or blame the source if they perceive a potential detrimental impact (for example, natural hazard information devaluing property). For many, an immediate perceived negative financial consequence will override a longer-term, lower-probability life-safety risk (Lechowska, 2018). Also, "a choice presented as avoiding a potential loss is more likely to be accepted than when it is framed as receiving a potential gain, even when the outcomes are identical" (Ball, et al., 2022).

Taig (2011) presents the following four basic attitudes or 'world views', taken from cultural theory (HSE, 2002), that determine behaviour in response to risk information. These views should be considered when communicating and making decisions about risk:

- Fatalists – see life as unpredictable and attempts at control as futile – they may not knowingly accept risks but will accept what is in store for them.
- Heirarchists – want well-established rules and procedures to regulate risks – they tend to see nature as 'robust within limits'.
- Individualists – see personal choice and initiative as most important – they tend to see risks as presenting opportunities, except those that threaten freedom of choice and action within free markets.
- Egalitarians – see the balance of nature as fragile and strongly fear risks to the environment, the collective good, and future generations – they tend to distrust expertise and demand public participation in decisions and react strongly against any 'Government knows best' approach.

Taig (2011) includes another contributing factor to risk perceptions – judgements about the source of risk information. This means whether the person or organisation providing the information is seen as trustworthy, or as providing confusing or conflicting messages. A high degree of trust makes it more likely that people will believe the information and act on it, whereas a low degree of trust makes it less likely that people will act or change their behaviour (Ball, et al., 2022). Importantly, simply providing more information does not necessarily lead to better communication. The information must be able to be sorted and assessed (understood) to create trust, not uncertainty.

It is important that people do not underestimate risk and fail to prepare, or think a risk is worse than it really is. Calming unnecessary fear is part of good risk communication. Either too much or too little concern can stop people acting to reduce risk (through complacency or paralysis). To prompt people to act, people must be appropriately concerned, or "just frightened enough" (Doyle, et al., 2020), and encouraged by a simple, clear explanation of how to reduce their risk.

Ultimately in communicating risk and encouraging action, the goal must be to listen, 'comfort the afflicted and afflict the comfortable', advise each person of what they have power to do and the rewards they can expect if they do it, and offer support to help them do what is needed. The consequences of inaction should also be addressed, but not made the focus. Then, people should make their own decisions based on their own risk appetite (Doyle & Becker, 2022).

Risk tolerance

Determining risk tolerability requires consulting affected communities and stakeholders to identify those most at risk.

The Introduction of this paper explained the need to understand risk tolerance in risk management. To understand risk tolerance, a range of stakeholders need to be engaged, and the outcomes should inform risk thresholds and risk treatment. Each of these key elements are discussed in the following subsections.

Engagement on risk tolerance

A 2013 review of international engagement and risk communication found the following elements are important when designing an engagement approach to establish risk tolerances (Saunders, Beban, & Kilvington, 2013):

- Building capacity for judgement, by providing a way for people to 1) understand complex risk concepts and 2) consider the implications for both them and their community. There should be a specific focus on them realistically considering both consequence and likelihood when making decisions about what is acceptable or not.
- Linking judgements on risk acceptability with decision-making for local government policy or action.
- Facilitating public and stakeholder input into different stages of planning process, including 1) contributing to knowledge about the local context of the hazards and risks, 2) developing policy and management options, and 3) assessing residual risk.
- Enabling public and stakeholder input to be considered alongside technical expertise.

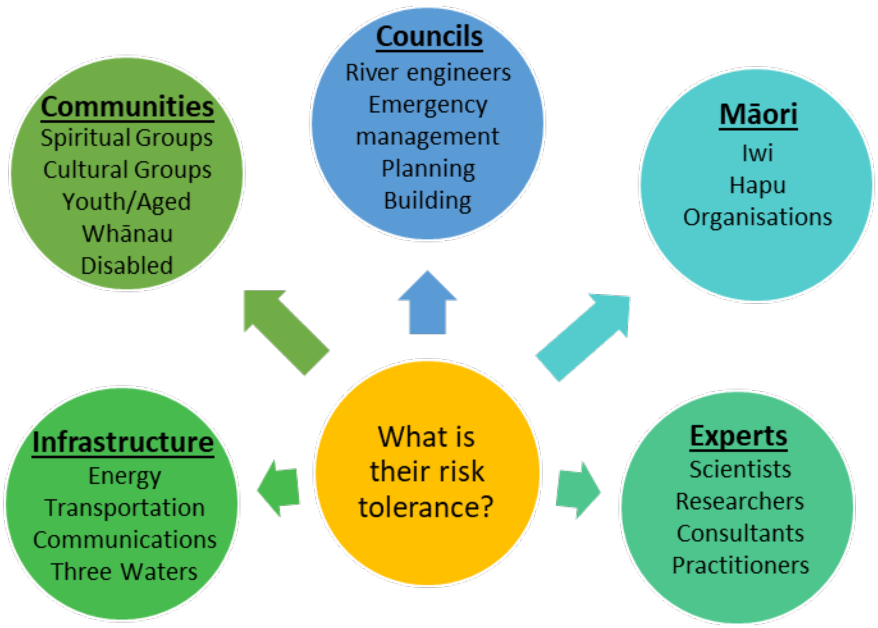

Figure 10 - Examples of engagement partners when investigating risk tolerances (adapted from Kilvington & Saunders, 2015)

One of the first actions is to determine who will make the decision on risk thresholds, how, and what the threshold will be used for (e.g., land use planning, emergency management, or building practice). Because hazard management often requires a cross-boundary, regional, and even national scale input, cross-agency expertise must be involved. While risk thresholds are typically set by political leaders, the process should be guided by expert opinion, knowledge, and experience, in addition to Council staff, infrastructure providers, iwi, communities, and other stakeholders (Figure 10, above). Who should be engaged depends on context, scale, and level of consequence.

After identifying groups to engage about risk tolerance, their views need to be reconciled using a robust and transparent decision-making process. Figure 11 shows the three elements required for robust engagement on risk tolerance: process, interpretation, and transparent integration of outcomes. For further information on criteria for each of the three elements, see Kilvington & Saunders (2015).

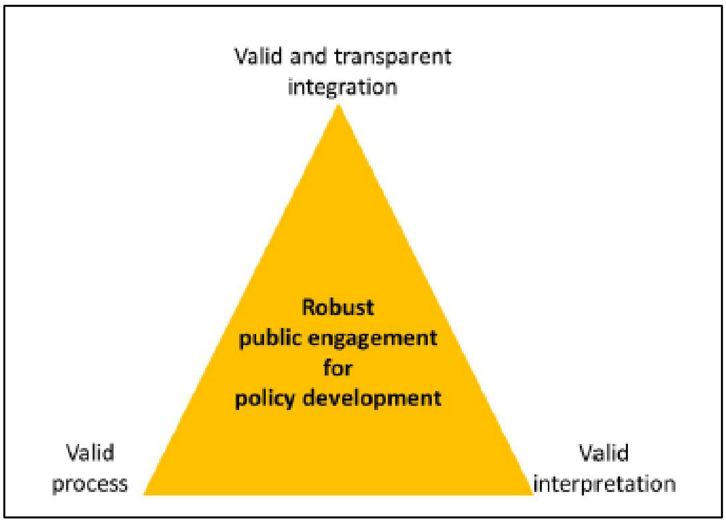

Figure 11 - Elements for a robust and transparent process to determine risk tolerances and thresholds (Kilvington & Saunders, 2015)

It is often not possible for stakeholders to reach consensus on risk tolerance, so a transparent process for reconciling different tolerances is required. For example, a community may tolerate a certain level of risk, while to the Council and experts the risk is intolerable, and the risk needs to be reduced or removed. These contrasting views need to reconcile and be ranked using an open and rational process to determine the risk threshold outcome. The Council may then seek a course of action that the community does not agree with, but the process to reach that decision is robust and transparent.

The Wharekawa Coast 2120 project demonstrates this process in addressing risk from sea level rise and climate change exacerbated hazards. Their *Community risk threshold, results and conclusions* report (Wharekawa Coast 2120, 2021) concluded that “nearly all community risk thresholds are reached earlier than those by the asset and emergency managers.” The respective priorities are shared and made available to everyone involved, and co-creation is prioritised in the process.

The following section provides an example of risk tolerance assessment.

Assessing risk tolerance

After engaging on risk tolerance, that tolerance can then be assessed. There is no national guidance on how to assess risk tolerance. While there are some examples (Kilvington & Saunders, 2015; Wharekawa Coast 2120, 2021), many are not documented for sharing or widely circulated.

In 2012, the Queensland Reconstruction Authority produced the guidance *Planning for Stronger, More Resilient Floodplains* (QRA, 2012). It promotes improvements in the flood mapping available for Queensland's floodplains and the land use planning mechanisms used to address development in these areas through a fit-for-purpose approach. The guidance encourages all Councils, regardless of resources or capacity, to undertake the floodplain management measures that are appropriate for their local government area. The guidance presents an 8-step process for determining levels of risk:

1. Select a flood likelihood to undertake the planning evaluation and create a flood map.
2. Identify exposure to hazard per lot.
3. Identify vulnerability to hazard severity per lot.
4. Identify tolerability to hazard severity per lot.
5. Calculate consequence score per lot.
6. Apply consequence score to likelihood x consequence matrix to determine risk level per plot.
7. Map risks and calculate area at risk.
8. Repeat evaluation for less frequent AEP levels.

Step four requires a risk tolerance assessment, including assessing community awareness and understanding, community perception of hazard, community preparedness, emergency management procedures/evacuation, level of protection from existing or proposed structural works, and the ability of critical infrastructure to remain operational during/after a flood event. Each step has a score associated with it, which provides a final level of risk in Step 6.

Table 12 provides an example of tolerability criteria that can be used to guide engagement with key stakeholders on their risk tolerance. The development of something similar could be further investigated for an all-hazards, Aotearoa New Zealand context.

Table 12 - Identifying Tolerability to hazard severity per lot (QRA, 2012)

Community Awareness/ Understanding	Community Perception of Hazard	Community Preparedness	Emergency Management* Procedures/Evacuation	Level of Protection to Lot from Existing or Proposed Structural Works (e.g. Levee)	Ability of use to remain operational during/after selected flood event (critical infrastructure only)	Score
OVERRIDING NEED TESTS^						
Unaware	Intolerant and not resilient	No individual preparedness, business continuity & social networks	For residential/critical infrastructure - no emergency services access to lot, or For non-residential - no evacuation procedures in place on lot	None	Not able to remain operational	0
Partially Aware	Fearful and generally not resilient	Limited individual preparedness, business continuity & social networks	For residential/critical infrastructure - limited emergency services access to lot, or For non-residential – limited evacuation procedures in place on lot	Less than 2%	N/A	1
Moderately Aware	Cautious and moderately resilient	Acceptable individual preparedness, business continuity & social networks	For residential/critical infrastructure – acceptable emergency services access to lot, or For non-residential – acceptable evacuation procedures in place on lot	2% - 1%	Reduced but acceptable operations	2
Generally Aware	Generally tolerant and resilient	Strong individual preparedness, business continuity & social networks	For residential/critical infrastructure – strong emergency services access to lot, or For non-residential – strong evacuation procedures in place on lot	1%	N/A	3
Very Aware	Tolerant and Resilient	Very strong individual preparedness, business continuity & social networks	For residential/critical infrastructure – very strong emergency services access to lot, or For non-residential – very strong evacuation procedures in place on lot	Above 1%	Able to remain fully operational	4
No persons or property affected, or emergency services/evacuation procedures and structural controls unnecessary						5

Read table from left to right and from bottom to top. The lowest score assigned must be the score chosen to identify Tolerability.

E.g. A community that is aware and tolerant of the flood hazard will score more than a community that is unaware or intolerant. Tolerability therefore can include common elements such as community awareness that are not lot-specific.

Equally, critical infrastructure that is rendered inoperable by the selected flood event, regardless of community awareness or perception must score 0. This is a lot-specific criterion.

^ Overriding economic or social need to remain in a flood hazard area must balance these imperatives with community awareness/understanding of the hazard to which they are subject, the community's perception of the hazard, their preparedness to such a hazard, and the extent of responsibility placed upon emergency management.

** Advice should be sought from local disaster management coordinator in evaluating emergency management procedures/evacuation plans*

Determining risk thresholds

It is important to have a clear process for determining risk thresholds to ensure there is a robust and transparent approach to putting risk-based policies into practice. For example, if a policy requires a risk to be ‘acceptable’, there should be a robust and transparent way of assessing that risk, now and over time. In other words, this should not rely on one person deciding based solely on their values, knowledge, and experience without using metrics.

Determining risk thresholds can be a contentious area of governance (e.g., Enright, 2015) and sometimes an alternative assessment method is preferred. One example of not using thresholds is from the Aotearoa New Zealand Covid-19 response, where the Ministry of Health took the approach that “Rather than setting fixed thresholds that must be met for any risk mitigation measures to be imposed, we can assess a broader picture of risk based on a number of public health considerations” (Hipkins, 2021).

The *GNS Stocktake* (Clarke et al., 2021) gives several examples of international well-established risk criteria frameworks. These are reproduced in Table 13 below, including a description of the threshold and the industries using the framework.

Table 13 is graphically represented in Figure 12 on a logarithmic scale to show how these examples of risk thresholds compare. Several of the examples do not specify ‘acceptable’ risk limits, so these are shown without green bars, and only amber (and red) ranges appear. Only the UK Health and Safety Executive (HSE) sets an ‘acceptable’ risk threshold, whereas the other examples only set ‘tolerable’ risk thresholds. Further, the tolerable risk limits vary significantly (spanning over three orders of magnitude), and some limits for tolerable risks are even lower than the upper limit of the HSE’s acceptable risk.

Table 13 - International risk criteria frameworks, from Clarke et al. (2021)

Organisation	Industry	Threshold	Risk tolerability (AIFR, unless otherwise specified)
HSE	Land-use planning around industries	Broadly acceptable limit	10^{-6} per annum (public and workers)
		Tolerable limit	10^{-4} per annum (public) 10^{-3} per annum (workers)
Netherlands Ministry of Housing	Land-use planning for industries	Tolerable limit	10^{-5} per annum (existing installations) 10^{-6} per annum (new installations)
Department of Urban Affairs and Planning, NSW Australia	Land-use planning for hazardous industries	'Acceptable' (tolerable) limit	$5x10^{-7}$ per annum (hospitals, schools, childcare facilities, old age housing) 10^{-6} per annum (residential, hotels, motels) $5x10^{-6}$ per annum (commercial development) 10^{-5} (sporting complexes)
Australian National Committee on Large Dams	Dams	Tolerable limit	10^{-4} per annum (existing dams, for public most at risk subject to ALARP) 10^{-5} per annum (new dams or major augmentation, for public most at risk subject to ALARP)
Australian Geomechanics Society guidelines for landslide risk management	Landslides (from engineered and natural slopes)	Suggested tolerable limit	AIFR: 10^{-4} per annum (public most at risk, existing slopes) 10^{-5} per annum (public most at risk, new slopes) Annual property risk: Makes suggestions for descriptors but does not suggest limits; suggests these should be defined by local authority
Hong Kong Special Administrative Region Government	Landslides from natural slopes	Tolerable limit	10^{-4} per annum (public most at risk, existing slopes) 10^{-5} per annum (public most at risk, new slopes)
Iceland Ministry for the Environment hazard zoning	Avalanches and landslides	'Acceptable' (tolerable) limit	$3x10^{-5}$ per annum (residentials, schools, day-care centres, hospitals, community centres) 10^{-4} per annum (commercial buildings) $5x10^{-5}$ per annum (recreational homes)
Roads and Traffic Authority, NSW Australia	Highway landslide risk	Implied tolerable risk	10^{-3} per annum

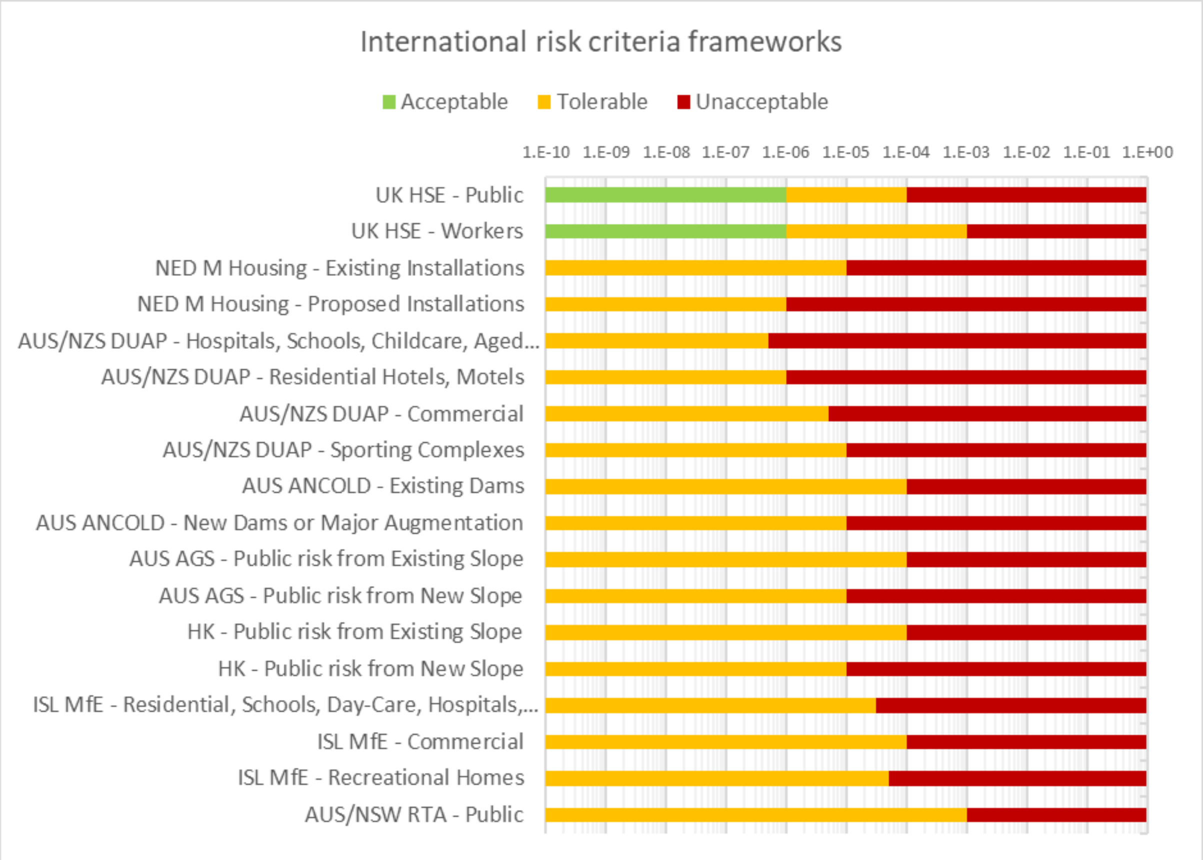

Figure 12 - International risk criteria frameworks, adapted from Clarke et al. (2021)

Further international examples of risk criteria are given in CCPS (2009), especially in land-use planning settings. These are reproduced graphically in Figure 13 below.

Again, in Figure 13, not all examples set thresholds for 'acceptable' and 'tolerable' risks. Where only an upper threshold for broadly acceptable risks is given, a green bar is shown without amber or red ranges. While these cases may include a tolerable range of risks, the region's bounds are not given and so it is unclear whether risk above the threshold would be considered tolerable or unacceptable. So, only the green, 'broadly acceptable' region is shown. Similarly, there were instances of thresholds for 'tolerable risks', but no threshold for 'broadly acceptable'. In these cases, no green region is shown, only amber and red ranges.

The three rows at the top of Figure 13 represent the upper and lower bounds for all instances of 'broadly acceptable', 'tolerable', and 'unacceptable' risks, respectively. These three rows—and Figure 13 generally—show that risk thresholds are highly variable and context-specific.

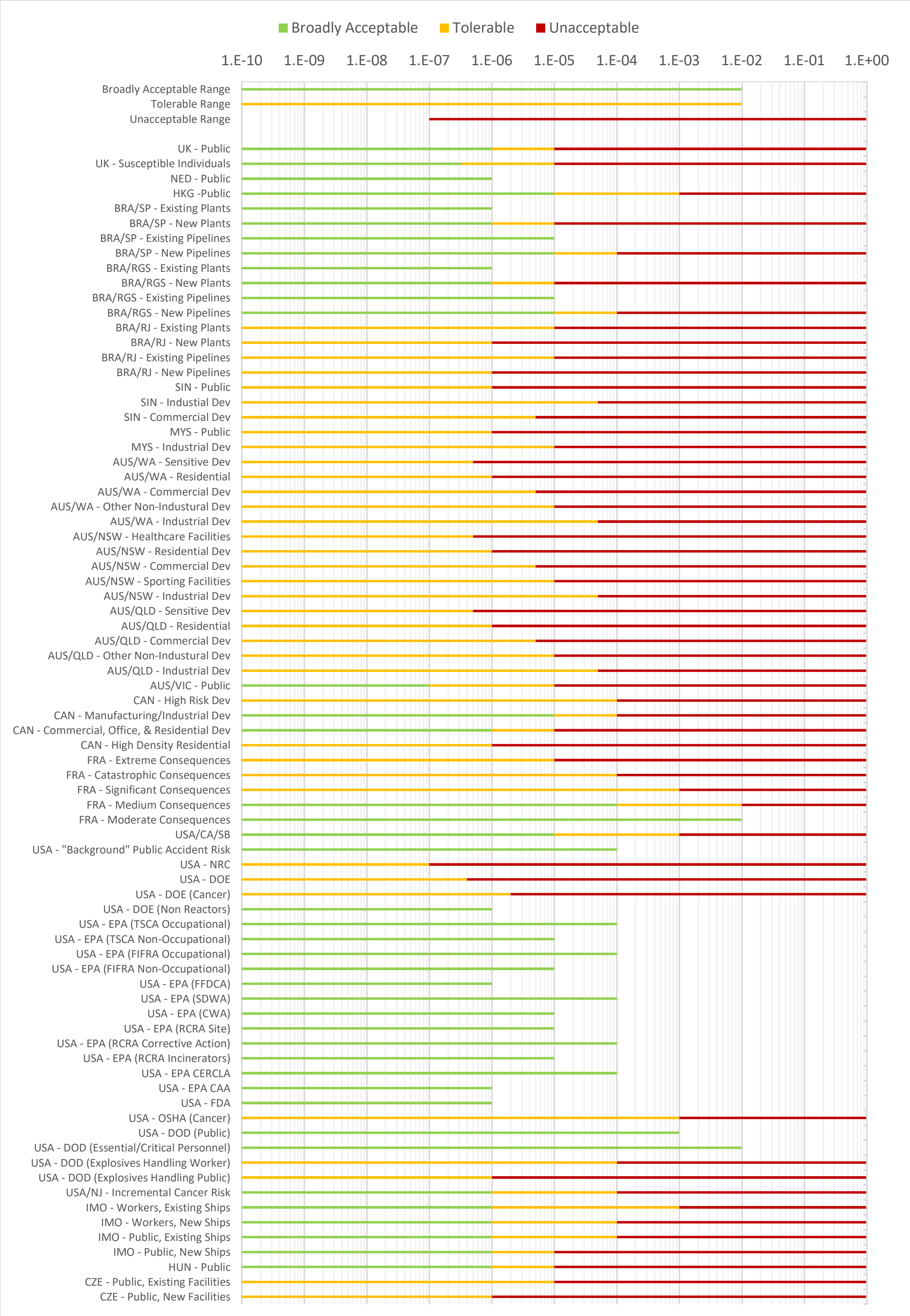

Figure 13 - International examples of risk thresholds (CCPS, 2009)

NZ life safety risk thresholds

The Levels of risk section of this document showed the risk terminology used in NZ national policy settings (Table 2). Complementing this, Table 14 gives examples from land use planning, and thresholds from DOC and MBIE for adventure activities. The table also shows the level of engagement that was undertaken, and the decision-maker who set the particular risk threshold.

Table 14 shows that life safety risk thresholds are being set at the national, regional, and district levels in Aotearoa New Zealand, with varied results. While there is some consistency with a life safety risk of 10^{-4} being unacceptable/intolerable/high risk, the varied terminology can cause confusion. The table also shows that when a regional or district plan includes levels of risk, regulatory consultation requirements are adhered to, as well as any other engagement that was undertaken while developing the policies

Table 14 - NZ Examples of life safety risk thresholds

Location	Context	Threshold(s)	Level of engagement	Decision-maker (year)
Christchurch	Port Hills Slope Instability (district plan)	10^{-4} (unacceptable)	Expert district plan consultation process (fast-tracked)	Christchurch DP Independent Hearings Panel (2012)
Otago	Regional Policy Statement (proposed)	For areas of **new development** where the greatest AIFR or APR is: • Less than 10^{-6} per year: re-categorised as acceptable; • Between 10^{-6} and 10^{-5} per year: re-categorised as tolerable; • Greater than 10^{-5} per year: re-categorised as significant For areas of **existing development** where the greatest AIFR or APR is: • Less than 10^{-5} per year: re-categorised as acceptable; • Between 10^{-5} and 10^{-4} per year: re-categorised as tolerable; • Greater than 10^{-4} per year: re-categorised as significant	Standard proposed RPS consultation process i.e., open to public and private organisations	Otago RC (proposed 2021)
Bay of Plenty	Regional Policy Statement Appendix L	High – greater than 10^{-4} Medium – 10^{-4} or less or greater than 10^{-5} Low – 10^{-5} or less	Standard proposed RPS consultation (open to public and private organisations)	Bay of Plenty RC (2014)
Matatā	Whakatane District Plan/BOP Regional Plan	10^{-5} for the fan head (High)	Engagement during retreat process with landowners; (standard process)	Whakatane DC, Bay of Plenty RC (2021)
National	Public Conservation Lands	Refer Table 15 - Proposed values for evaluation of visitor individual risk from natural hazards (Taig, 2020a), below.	Limited	DOC (under review, 2020)
National	Adventure activities	Single incidents that result in more than five deaths	Open consultation	MBIE (under review, 2021)

Plotting Table 14 in Figure 14 (below) again shows the variability in risk thresholds. Figure 14 also demonstrates the inconsistent terminology used in Aotearoa New Zealand.

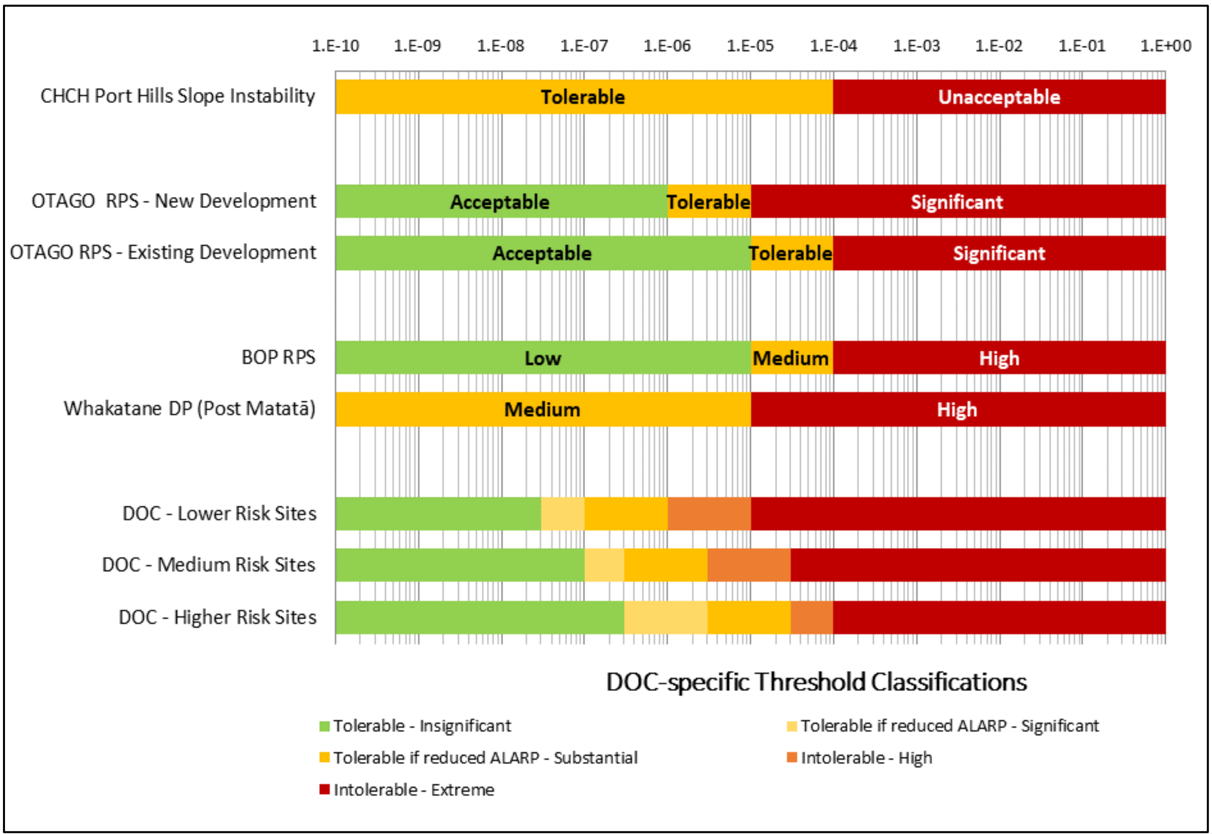

Figure 14 - NZ examples of fatality risk thresholds

Aotearoa New Zealand building system

Aotearoa New Zealand's building code and built environment system is responsible for managing risks associated with living in, or using, buildings and structures. Governing pieces of legislation are the Building Act 2004 and Building Regulations 1992 (the Building Code). These provide overall direction for the building system, but they do so without setting explicit risk thresholds or tolerances. From Building Regulations 1992 (emphasis added):

B1.3.1 Buildings, building elements, and sitework **shall have a low probability** of rupturing, becoming unstable, losing equilibrium, or collapsing during construction or alteration and throughout their lives.

B1.3.2 Buildings, building elements, and sitework **shall have a low probability** of causing loss of amenity through undue deformation, vibratory response, degradation, or other physical characteristics throughout their lives, or during construction or alteration when the building is in use.

Sitting under legislation, *AS/NZS 1170 Structural Design Actions* is the standard most engineering professionals designing buildings in Aotearoa New Zealand use. The standards themselves are hazard-based, rather than risk-based – internationally, risk-based design is not generally accepted by national standards and codes (ISO, 2015). In practice, this means designers are not required to make explicit decisions on acceptable levels of risk in their projects. Instead, they apply the risk thresholds that sit behind *AS/NZS1170*. Supplementary material to the standard (*NZS 1170.5 Supp 1:2004 Structural Design Actions Part 5: Earthquake*

Actions – New Zealand – Commentary, SNZ, 2004) states "Internationally, an accepted basis for building code requirements is a target annual earthquake fatality risk in the order of 10^{-6} (ISO 2394:1998)". The referenced standard has since been republished (ISO, 2015) and still points to 10^{-6} as an international benchmark for broadly acceptable annual fatality rates.

However, even for engineering designers who are aware of the implicit fatality risk threshold in *NZS1170*, structure collapse probability is a step removed from fatality risk due to building collapse. Again, from *NZS1170.5 Commentary* (SNZ, 2004):

> *In design terms it is generally accepted that fatality risk will only be present if a building fails, i.e., collapses. The maximum allowable probability of collapse of the structure is then dependent on the probability of a person being killed, given that the building has collapsed. This conditional probability will be dependent on structural type and other factors and is likely to be in the range 10^{-1} to 10^{-2}...Acceptable annual probabilities of collapse might therefore be in the range 10^{-4} to 10^{-6}. These values are inclusive of any collapses that might arise from design and construction errors (i.e., lack of compliance with the provisions of this Standard and the NZBC) which from experience will be the major contributors to collapses that do occur.*

The indicated probability of collapse (10^{-4} to 10^{-6}) is reflected in the Joint Committee on Structural Safety's *Probabilistic Model Code* (JCSS, 2001), which suggests a target failure rate of 10^{-5} for 'typical' buildings. The *Probabilistic Model Code* is the basis for ISO 2394:2015, which then is the basis for *NZS1170*.

Although there is rigorous technical rationale sitting behind Aotearoa New Zealand's design standards, the underlying risk decisions are removed from typical design practice, and so from the people it affects most affects. Even for informed designers who understand the inherent target collapse or fatality rates behind the design standards, it is unclear in specific structural design how to change their designs to measurably change those probabilities. For example, how many extra pieces of steel reinforcing bar must go into a concrete wall to lower a building design's collapse risk from 10^{-3} to 10^{-4}? Designers tend to consider forces and capacity (a structure's vulnerability), but these characteristics are rarely, if ever, translated into a resulting collapse—or fatality—risk in the design process.

Additionally, because designers are not necessarily aware of the risk threshold sitting behind *NZS1170* and other widely used design standards, their clients, building owners, and users are also not aware of the risk threshold they have accepted.

Earthquake-prone buildings

The earthquake-prone building (EPB) system is designed to identify and manage buildings that present the most significant risks to life in seismic events in Aotearoa New Zealand. It is governed by the Building (Earthquake-prone Buildings) Amendment Act 2016 and involves rating buildings by their structural capacity to resist seismic loading. This is presented as a percentage of the capacity the building would have if it were designed on, or after, 1 July 2017. This has come to be referred to as *%NBS*, where NBS refers to 'New Building Standard'. A rating of <34*%NBS* (meaning 33*%NBS* or lower) is the threshold for whether a building is earthquake-prone or not. The Building Act 2004 determines a building is legally earthquake-prone if:

(1) having regard to the condition of the building or part and to the ground on which the building is built, and because of the construction of the building or part –

(a) the building or part will have its ultimate capacity exceeded in a moderate earthquake; and

(b) if the building or part were to collapse, the collapse would be likely to cause –

(i) injury or death to persons in or near the building or on any other property; or

(ii) damage to any other property.

The EPB system is tied to the 'new' building standard in effect on 1 July 2017, meaning the standard a new building would have been designed to at that date. For most buildings in Aotearoa New Zealand, this was, and at time of writing still is *AS/NZS1170 Structural Design Actions* (various sections were published between 2002 and 2004). The key point of the EPB system for risk thresholds is that it inherently benchmarks itself against the underlying risk thresholds of *AS/NZS1170*, described above.

Beyond using the same underlying risk thresholds as newly designed buildings, the EPB system sets the threshold of <34*%NBS* between unacceptable and tolerable risks. This threshold has been critiqued over the years, including a notable comprehensive 2006 report from the New Zealand Society for Earthquake Engineering. This called for the threshold to be set at <67*%NBS* rather than <34*%NBS* (NZSEE, 2006). However, Taig (2012) demonstrated to MBIE that the benefits of strengthening buildings beyond *34%NBS* reduced significantly relative to required investment when compared to strengthening buildings just to *34%NBS*. This means that setting the EPB threshold at a higher *%NBS* rating (than *34%NBS*) would have required significantly more resources and investment but would not necessarily have increased safety for occupants and users. This is a practical example of the ALARP principle – buildings with ratings between 34*%NBS* and 67*%NBS* would have required grossly disproportionate resources and effort to reduce their risk relative to the benefit of the reduction.

The EPB system is an effective system with clear thresholds. But it does not technically convey risk. Buildings are assessed by their geographic 'seismic risk zone', as defined in the Building Act 2004, but they are more accurately seismic *hazard* zones (based on the '*Z* factor', from *NZS1170.5*). Additionally, *%NBS* is more realistically a measure of a building's capacity to resist seismic forces, or its vulnerability. So, despite clearly setting its own thresholds, the EPB system represents an imperfect consideration of risk.

It is also unclear how or if the risk tolerance in the Building Code complements other legislation that applies to building users, specifically the Health and Safety at Work Act 2015 (HSWA). Owners of EPBs have timeframes (between 7½ and 35 years) to either strengthen their buildings so that they are no longer earthquake-prone or demolish them. This implies the increased seismic risk posed by an EPB (relative to a *100%NBS* building) is tolerable, if only for the prescribed timeframe.

But there has been well documented and publicised[4,5] confusion from building owners and tenants about their responsibilities as Persons Conducting a Business or Undertaking (PCBUs)

[4] https://www.stuff.co.nz/national/129170022/no-need-to-vacate-earthquakeprone-buildings-mbie-says?rm=a

under the HSWA. Several tenants—including central government agencies[6,7]—have vacated buildings after engineering assessments resulted in low ratings, even though EPB legislation does not require them to. Most seem motivated by aversion to liability under the HSWA for not eliminating or minimising seismic risk (Nuth, et al., 2021). This is despite WorkSafe guidance stating "If you're a PCBU who owns or occupies an earthquake-prone building and you're meeting the earthquake performance requirements of the Building Act 2004, we are not going to enforce to a higher standard under HSWA" (WorkSafe, 2018). That means the risk thresholds of the Building Act 2004, and so the earthquake-prone building policy, satisfy requirements of PCBUs under the HSWA. EPBs can be occupied during their strengthening timeframes, but not everyone understands. MBIE sought to clarify this in their *Seismic Risk Guidance for Buildings* (MBIE, 2022).

NZ Department of Conservation

Aotearoa New Zealand's Department of Conservation (DOC) is responsible for managing public conservation lands and waters (PCL), and the activities that take place on them. This means they manage visitors with a significant range of abilities and experience levels, undertaking a range of activities of varying levels of inherent risk, taking place across the entire country. DOC must also manage risk to its staff.

DOC's first Visitor Safety Principle is notable: *"The range of outdoor recreation experiences available to visitors will be preserved wherever possible"* (DOC, 2017). That means, while many outdoor recreation activities carry inherent risks (that are not negligible), they prefer not to protect visitors and staff by completely isolating them from, or removing, the hazard. This acknowledges that some outdoor recreation experiences are valuable and should not be lost because of a hazard. DOC's strategy was to quantify risks and be able to compare levels to provide context for what is or should be tolerable, as an organisation but also to society.

To help develop its risk management policies, DOC engaged GNS Science and TTAC Ltd (UK). The resulting work (Taig, 2020a; Taig, 2020b) helped determine appropriate responses to different levels of natural hazard risk, for both visitors and staff. DOC uses fatality rate as its main risk metric, but considers it at different three levels:

- Individual risk
- Staff risk
- Societal risk

For individuals, DOC considers an average visitor to PCL and fatality risk, on a per day, or per visit, basis. This is the expected extent of exposure for most visitors. DOC considers staff risk on an annual basis because staff have more regular, and longer periods of exposure to hazardous activities in their roles. Societal risk is aggregated from individual risk, taken over an entire year, rather than per day.

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[5] https://www.stuff.co.nz/opinion/129284947/earthquakeprone-legislation--it-is-time-for-a-rethink
[6] https://www.stuff.co.nz/national/128753583/ministry-of-education-to-close-head-office-in-wellington-due-to-earthquake-risk-1000-staff-to-work-from-home
[7] https://www.stuff.co.nz/business/125908188/asteron-centre-likely-out-of-action-for-at-least-three-months

The DOC risk matrix uses a five-step scale of 'significance levels', to describe risk: 'extreme', 'high', 'substantial', 'significant' and 'insignificant'. Three evaluation categories— 'intolerable', 'tolerable if reduced to ALARP', and 'tolerable'– cover the top two, middle two and lowest significance levels, respectively. Each evaluation category describes the action required at this level of risk (Clarke et al., 2021). The proposed fatality risk thresholds and associated activities and risk treatment options are shown for individual visitors in Table 15, below.

Table 15 - Proposed values for evaluation of visitor individual risk from natural hazards (Taig, 2020a)

			Fatality risk per Day/Single Visit		
Significance Level	**Evaluation Category**	**Action Required**	**Lower Risk**	**Medium Risk**	**Higher Risk**
Extreme	Intolerable	HALT until risk reduced	$>10^{-5}$	$>3x10^{-5}$	$>10^{-4}$
High		Continue ONLY after corporate review etc	$>10^{-6}$	$>3x10^{-6}$	$>3x10^{-5}$
Substantial	Tolerable if reduced ALARP	Explore practicable risk reduction options (prioritise SUBSTANTIAL)	10^{-7} to 10^{-6}	$3x10^{-7}$ to $3x10^{-6}$	$3x10^{-6}$to $3x10^{-5}$
Significant			$3x10^{-8}$ to 10^{-7}	$>10^{-7}$ to $3x10^{-7}$	$3x10^{-7}$ to $3x10^{-6}$
Insignificant	Tolerable	None	$<3x10^{-8}$	$<10^{-7}$	$<3x10^{-7}$

Although the DOC approach is based on individual risk, DOC has also considered the societal risk, or risk of an incident or event that would harm multiple people occurring. DOC has not set societal risk thresholds, but using the following as guidance, they define what an event is, broadly categorised as a 'severe event'. This includes an event killing five or more people, any multiple-fatality event where victims are particularly valued (children) and any multiple-fatality event directly attributable to failings by DOC.

The risk profile of a DOC worker can vary significantly depending on their role, so two risk metrics are provided for staff: 1) the AIFR for workers who are regularly exposed to natural hazard risks, such as rangers, and 2) a daily fatality risk for staff exposed to one-off or occasional natural hazard risks. This also reflects the time-specific exposure of staff to natural hazard risk. The risk profile for staff is provided in Table 16.

Table 16 - Proposed values for evaluation of DOC Workers' natural hazard risk (Taig, 2020a)

Significance Level	Evaluation Category	Action Required	**Annual Fatality Risk** Permanent or Temporary Staff Regularly Exposed to Natural Hazard	**Daily Fatality Risk** One-off or Occasional exposure to Natural Hazard
Extreme	Intolerable	HALT until risk reduced	$>3x10^{-4}$	$>3x10^{-5}$
High		Continue ONLY after corporate review etc	$>10^{-4}$	$>3x10^{-6}$
Substantial	Tolerable if reduced ALARP	Explore practicable risk reduction options (prioritise SUBSTANTIAL)	10^{-5} to 10^{-4}	$3x10^{-7}$ to $3x10^{-6}$
Significant			10^{-6} to 10^{-5}	10^{-7} to $3x10^{-7}$
Insignificant	Tolerable	None	$<10^{-6}$	$<10^{-7}$

Comparing life safety risk thresholds

Taig, Massey & Webb (2012) produced a risk comparison (Figure 15, below) showing the annual individual and lifetime fatality risk against existing risk threshold criteria, Aotearoa New Zealand natural hazard risks, and other risks (for example, cancer, heart disease, road accidents, falls, drownings). This helped Christchurch City Council to make decisions about risk tolerability in the Port Hills after the 2010/11 earthquake sequence. Key considerations from Taig, Massey & Webb (2012) for the table include:

1. *With reference to the left-hand area of [Figure 15] ('Existing criteria'), the fact that the risk is pre-existing and is associated with where people choose to live rather than being imposed by other people suggests that tolerability threshold should be selected from the upper, rather than the lower, half of the chart.*
2. *The central area of [Figure 15] ('NZ Natural Hazard Risks') suggest that 10^{-5} annual individual fatality risk would be too low a threshold of tolerability; tens if not hundreds of thousands of New Zealanders probably experience natural hazard risk at or above this level already.*
3. *As regards the right-hand side of [Figure 15] ('Other NZ risks'), the average lifetime risks associated with cancer and heart disease (each about 3 x 10^{-3} annual individual fatality risk) are too high to be considered primary causes of death in New Zealand and other developed countries and it would be unprecedented to tolerate public exposure to a particular source of accident risk at such levels.*
4. *An obvious starting point for consideration by Christchurch City Council would be an annual individual fatality risk of 10^{-4} per year. This is consistent with the thresholds of tolerability:*
    - *Adopted by the Australian National Committee on Large Dams and suggested by the Australian Geomechanics Society for existing dams/properties*

– *Adopted by the UK Health and Safety Executive for members of the public, and*

– *Adopted in civil aviation for protecting people near airport runways in the UK.*

It would imply that many hundred (or possibly thousands or more) households in New Zealand were already at intolerable risk from other hazards such as landslide and tsunami, but such cases are largely already subject to substantial initiatives to reduce risk.

In the 10 years since this report was published in 2012, a number of key statistics may change the outcome, for example:

- 2021/2022 holiday period drowning rate: 180% increase over the 5-year average (Water Safety NZ, 2022)
- 2019 Whakaari eruption: 22 Deaths
- Covid-19 pandemic and associated deaths

We recommend this be updated to provide a more current understanding of risk comparisons.

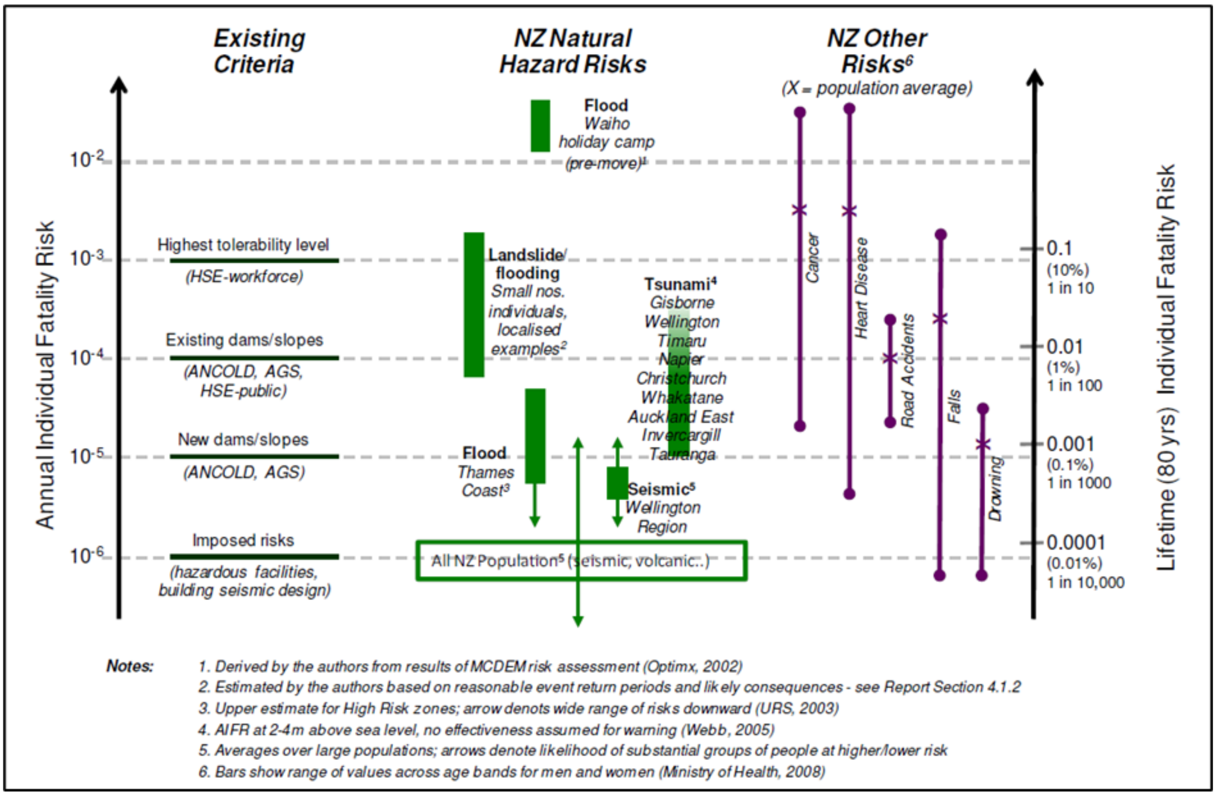

Figure 15 - Comparison of New Zealand Risks and Existing Criteria (Taig, Massey, & Webb, 2012)

Similarly, a more recent (2020b) report for DOC compares causes of accidental death for the Aotearoa New Zealand population (Figure 16), but the data is limited to 2011-2015, and excludes deaths from natural hazards (like earthquakes, volcanic activity, landslides) and other more recent significant events like the Covid-19 pandemic.

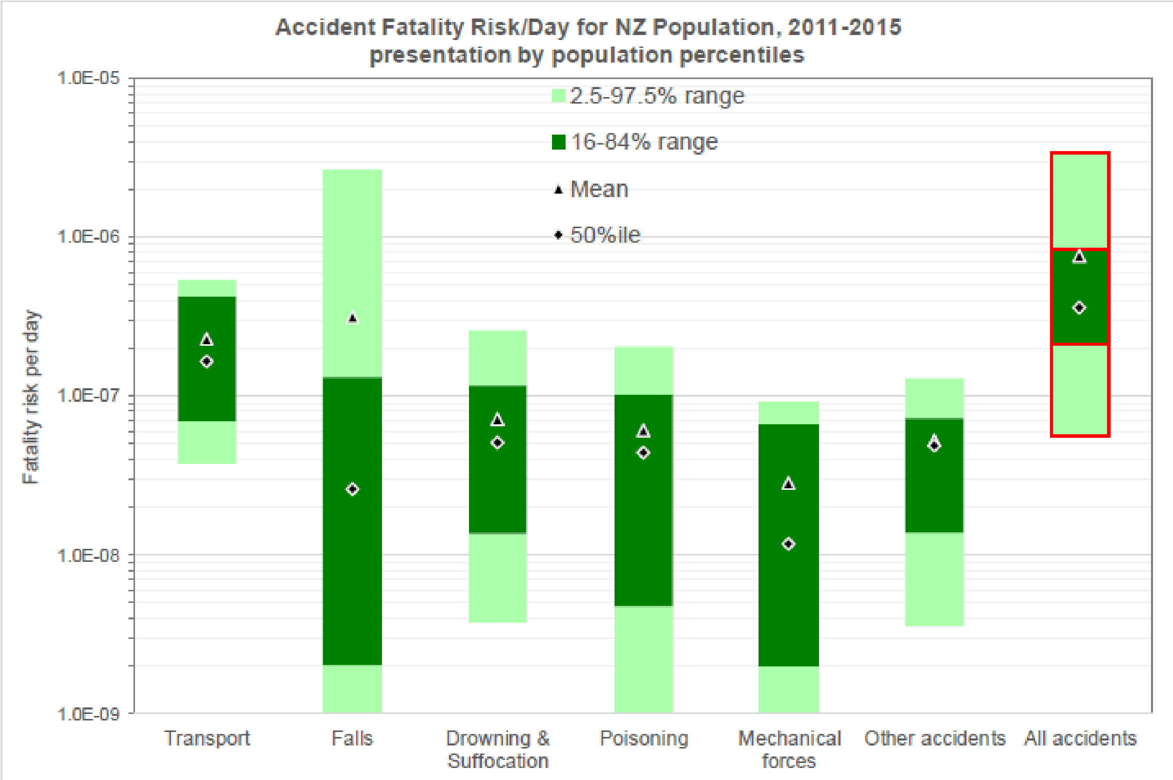

Figure 16 - Contributors to New Zealanders' Daily Risk of Accidental Death, 2011-2015 (Taig, 2020b)

While acknowledging the above limitations, Taig (2020b) does present the following comparisons:

- The average risk from transport accidents (largely motor vehicle crashes on the roads) is just over $2x10^{-7}$ per day.
- Most New Zealanders experience fatality risk between 10^{-8} and 10^{-7} per day.
- Well over half of New Zealanders experience daily risk greater than 10^{-7} from accidental causes (other than transport).

These comparative figures show that New Zealanders are exposed to a variety of risks, from both natural hazards and other sources. These risks range from 'high' to 'low', and while not addressed here, mitigation options would lower risks before they manifest.

Methodologies for risk assessments to evaluate risk

Based on the standard risk management process, there are a variety of risk assessment methodologies available to assess different hazards. Rather than there being one set methodology, the ISO31000 standard provides the framework and process for hazard-specific methodologies. This has allowed for internationally accepted hazard-specific risk assessment methodologies to be developed and used. Examples of these hazard-specific methodologies and where in Aotearoa New Zealand they have been used are provided in Table 17.

Table 17 - Common risk assessment methodologies in use in New Zealand

What	Source	Examples of use
Landslides	Australian Geomechanics Society Guideline for landslide susceptibility, hazard and risk zoning for land use planning (2007)	Port Hills, Christchurch Matata GNS Science Landslide Guidelines
Sea Level Rise/coastal hazards	MFE Coastal hazards and climate change guidance (2017)	Hawke's Bay
Active Faults	MFE Planning for development of land on or close to active faults guidance (2003)	Kapiti Coast; Hurunui; Manawatu
Flooding	NZS9401:2008 Managing flood risk – a process standard	Otago
Liquefaction	EQC / MBIE / MFE Planning and engineering guidance for potentially liquefaction-prone land (2017)	Canterbury

Each of the above methodologies includes a risk evaluation component, which involves an assessing both risk tolerance and risk thresholds. The risk thresholds should be assessed against pre-agreed criteria to determine whether a risk is acceptable, tolerable, or intolerable.

Including risk tolerance in Aotearoa New Zealand's hazard risk management framework

This literature review has shown that assessing risk tolerance and the use of risk thresholds are inconsistently, or simply not, applied. Risk assessments are necessarily highly variable and context-specific, with different hazards requiring different risk analysis methodologies. To account for this, we highlight the need for a flexible yet consistent approach to assessing risk tolerance with the following key features:

1. The risk analysis process should be documented and result in a clear level of risk. Existing risk analysis processes can be used, which allow different sectors to follow best practice for the specific context or hazard. The risk analysis should be documented and result in a clear level of risk (e.g., 'intolerable', 'tolerable', or 'acceptable') so that the level of risk output can be directly considered against risk thresholds.
2. Risk thresholds should be pre-set through an agreed process. For example, 'intolerable', 'tolerable', and 'acceptable' risks would be established across different settings (e.g., impacts to people, the economy, the environment, etc.) for specific timeframes. This would allow the results of the risk analysis to be assessed against consistent risk thresholds to determine risk tolerance.
3. Policy options should directly align with agreed risk threshold terminology. Consistent terminology across policy would allow certain levels of risk to directly correspond with certain risk treatment options. For example, 'intolerable', 'tolerable', and 'acceptable' risks could correspond with 'removal', 'reduction', or 'monitoring' policy response options, respectively. This would lead to more consistent risk management outcomes, while still accounting for specific hazards and context.
4. Risk treatment should be implemented through engagement based on the policy options available for the risk tolerability. This enables communities to decide which risk treatment option is implemented, while providing national consistency on the policy approaches used for different levels of risk tolerance. For example, where national legislation specifies a 'tolerable' level of risk, regional or district level policies can provide the appropriate response (e.g., reduction, adaptation, or monitoring).

An Australian example of land use planning responses to levels of risk is provided in Appendix A3 Land use responses to levels of risk. For each risk level (acceptable, tolerable, intolerable) it shows the available land use responses (implementation actions) that could be incorporated into regional and district level planning. This includes possible transition strategies, planning options, and land uses that may be appropriate for the specific risk. A similar approach could also be applied for emergency management, buildings, and other interests.

Summary

This paper outlines the importance of risk thresholds, and how they are—or are not—included in various settings. The most significant theme from this review is the **current inconsistency in assessing risk tolerance and risk thresholds**.

Robust and transparent risk tolerance assessments and processes are important to manage risks effectively and implement risk reduction initiatives. Understanding risk tolerance is a critical part of the risk management process, but **Aotearoa New Zealand does not have an agreed local, regional, or national regulatory approach to determining risk tolerance and risk acceptability**. A key part of effective risk management is identifying the boundaries between different levels of risk, such as acceptable, tolerable, and intolerable risks. **Toka Tū Ake EQC is interested in this so we can proactively support risk reduction to reduce the Crown's liability, and to help develop risk thresholds in the Natural Hazards Portal**.

The Introduction presents **basic terminology** including risk tolerance and risk thresholds and describes why Toka Tū Ake EQC has an interest in them.

What is risk? summarises key features of risk. Under the CDEM Act, risk is defined as the likelihood and consequence of a hazard, which can be further broken down to exposure and vulnerability.

Levels of risk discusses terminology for levels of risk, and what terms are being used in Aotearoa New Zealand. A key finding was that **terminology for levels of risk** (like 'acceptable', 'tolerable', 'intolerable') **is highly varied at both a national and sub-national level**, with **no consistency across agencies or policies**. How to measure risk discusses various methodologies to **measure risk**.

Risk to what provides some direction on **what risks can be assessed**, based on the legislative themes of wellbeing (health and safety, economic, cultural, property, environment). Different methods are presented for each of these elements, as well as to two multi-criteria risk metrics which show examples of how combined risk metrics can work across the wellbeing themes. A key finding was that both the level of individual and societal concerns must be considered when deciding whether a risk is intolerable, tolerable, or broadly acceptable.

Risk to whom outlines approaches to assessing **who is at risk**, from both an individual and societal perspective. When assessing either individual or societal risk, determining risk tolerance requires engaging with the people at risk. This is important for setting risk thresholds, and there are three key features of successful risk tolerance engagement: robust process, robust interpretation, and transparent integration of outcomes. Risk tolerance can be assessed after identifying who is at risk. Understanding risk tolerance requires engaging a range of stakeholders to inform a risk tolerance framework.

Risk perception compares 'perceived' and 'actual' risk and considers the role **risk perception** plays in risk management. Risk perception may ultimately be more important than actual risk in affecting behaviour and choices. A high degree of trust in decision-makers and risk communicators is vital to change behaviour or prompt action. In communicating risk and encouraging action, we must listen, "comfort the afflicted and afflict the comfortable", advise

each person of what they have power to do and the rewards they can expect if they do it, and offer support to help them do what is needed.

Risk tolerance discusses the importance of the three elements required for robust engagement on risk tolerance: process, interpretation, and transparent integration of outcomes. It also provides an example of how we can assess tolerability through community awareness and understanding, community perception of hazard, community preparedness, emergency management procedures/evacuation, level of protection from existing or proposed structural works, and the ability of critical infrastructure to remain operational during/after an event.

Determining risk thresholds provides an overview of international and national thresholds for life safety, typically represented as an annual individual fatality rate. A key finding is that both internationally and nationally, **risk-to-life thresholds are highly variable and context-specific**. Various internationally accepted methodologies for different contexts are used to determine these thresholds. This section compares life safety risk thresholds, which demonstrate the inconsistencies of risk tolerances and thresholds.

To bring a consistent national approach to risk thresholds, Including risk tolerance in Aotearoa New Zealand's hazard risk management framework recommends **a consistent approach to assessing risk tolerance** as a starting point for a discussion on this issue. This concept is a starting point for a wider conversation on a national risk framework which can guide the review of the RMA, the implementation of the Building Act, and other national and sub-national mechanisms.

As a result, summary answers to the questions provided in the Introduction are given below:

1. *What is risk?*

   The CDEM Act defines risk as "the likelihood and consequences of a hazard". This definition can be broken down further. Consequences depend on the specific natural hazard event, the type of hazard, and how they may affect human life and property. Life and property exposure to the hazard and the vulnerabilities of the specific people and property determine the consequence (for example, a person's pre-existing medical conditions, or a building construction typology).

2. *How can risk be measured?*

   There are many ways to measure risk, including methods to assess individual and/or societal life safety risk; risk to property and infrastructure; and financial risk. Risks can be measured qualitatively, quantitatively, or using a mixture of both. Risks can be assessed individually, or combined into multi-risk metrics, where more than one risk is assessed together. Different risks and contexts have different methodologies to determine their overall risk.

3. *What are risk thresholds, and why are they important?*

   A risk threshold is the limit beyond which a different response is required to manage the level of risk. It builds on risk tolerance by quantifies it with a precise figure or measure. This means that a risk threshold gives a clear quantitative or qualitative measure of the risk and its acceptability. Determining the risk threshold requires engagement with key stakeholders to understand their risk appetite and risk tolerance.

4. *What is the relationship between risk thresholds and risk tolerance?*

Risk tolerance is a level of risk within a range that society accepts to secure net benefits. It describes a range of risk, which needs to be monitored, reviewed, and reduced further if possible. We should understand risk tolerances before calculating the threshold that triggers response actions for intolerable levels of risk.

5. *How are risk thresholds determined, internationally and in New Zealand?*

Internationally, and in New Zealand, there is high variability in how risk thresholds are determined, which is context specific. What is common in setting thresholds is that an accepted, robust, and transparent methodology is used to determine the risk thresholds.

6. *Who determines risk thresholds?*

There is no national or international direction for setting risk thresholds in New Zealand, so all levels of Government currently have a role in determining risk thresholds. Legislation (for example, the Building Act 2004, RMA, CDEM Act) refers to different levels of risk (like 'significant' or 'acceptable') and takes varying approaches to who is responsible for setting the thresholds. Under the RMA, it is not clear whether a regional or territorial authority is responsible for setting the risk thresholds. In practice, there are examples of both regional and territorial authorities setting thresholds, either through regional policy statements or district plans.

7. *What national direction is needed?*

We propose that risk tolerance evaluation is incorporated into risk management in Aotearoa New Zealand. This includes making terminology and expected outcomes consistent. This requires the following key features:

- Use of existing risk analysis processes, which allows different sectors to follow best practice for the specific context or hazard.
- An agreed process to set risk thresholds, which are associated with finite timeframes.
- Development of policy options directly aligned with agreed risk thresholds needs consistent terminology and risk criteria in place.
- Risk treatment implemented through engagement that enables communities to decide which risk treatment option is implemented.

Based on this literature review, the 2023 Toka Tū Ake EQC companion paper "Risk Tolerance Methodology – All Hazards, All Risks" proposes a way to integrate a risk tolerance assessment into our current hazard risk management approaches, i.e., at the evaluation stage of the risk assessment process (typically based on ISO 31000:2018). It provides consistency while being adaptable to suit varying contexts and timeframes, including for decision-makers across local, regional, and central government levels, and within the private sector. This will enable more robust and transparent risk-based decision-making. The paper also proposes nationally consistent risk terminology for risk tolerance.

Further research

Risk tolerance

Developing an approach to assess risk tolerance should be investigated further, based on experiences in Aotearoa New Zealand and internationally. The framework presented in Table 12 from the Queensland Reconstruction Authority provides a starting point for further discussing how to assess risk tolerance, and how to use the results to guide risk threshold processes, and implementation. Other initiatives relating to engagement methods also need to be assessed and explored, like the recent Toka Tū Ake EQC-funded project Let's Talk About Risk: Enhancing Community Engagement on Natural Hazard Risk (Project No 3056) and discussions with other Government and sub-national agencies about their approach to setting risk thresholds.

Risk comparisons

Examples from the New Zealand Department of Conservation compared risks across natural hazards, illness/health, and accidents. This is useful to understand how thresholds relate across many different risks, and whether they are consistent. The information in this section is outdated, with data limited to 2015. Since 2015, a number of events may affect these comparisons, notably the Covid-19 pandemic, the 2019 Whakaari/White Island eruption, and increased drownings over the 2021/2022 summer. An updated comparison that includes these events, together with road safety risk thresholds, could contribute to further discussions on risk tolerance.

Lessons from the Covid-19 pandemic

While we were researching for this document, Aotearoa New Zealand was continuing its response to the Covid-19 pandemic. There are many learnings about risk management from a health crisis perspective that could be investigated further, and their implications for natural hazard risk management. Many of the key decisions about risk thresholds for the response to the Covid-19 pandemic are not yet publicly available, so we have not included them in this discussion document. But these decisions have implications for, and can help us understand, how decisions on risk thresholds are being made, who is making these decisions, how and what expert input is used in decision-making, and how much engagement is occurring with key stakeholders (including the public).

Natural Hazards Portal

The information in this paper will help us to develop the Natural Hazards Portal, particularly the intended risk tolerance assessment tool. It is envisaged that this tool will enable people to determine their own risk tolerance using a 'self-service' assessment. We intend the risk tolerance criteria used in the Natural Hazards Portal to reflect any further or wider work done investigating risk tolerance, and to be suitable for all stakeholders and local, regional, and national priorities. Further investigations are required to help develop this risk tolerance assessment.

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Appendices

A1 Risk management process

The United Nations guidelines for national disaster risk assessment (UNISDR, 2017) refer to the ISO 31000 standard as the most commonly used approach to risk management. The risk management process includes the following key steps:

- establish the context in which you are working,
- identify risks,
- analyse risks,
- evaluate risks, and
- treat risks.

Throughout these steps, concurrent activities of monitoring and reviewing, and communication and consultation occur to ensure a robust risk management approach.

Risk management for natural hazards can use the same systems process as for other types of risk, like financial risk. This process is outlined in International Standard 31000. The process is flexible and generalised enough in its framework to incorporate the complexity, uncertainty and range of treatments available for risks resulting from natural hazards. The risk management framework is shown in Figure 17 below.

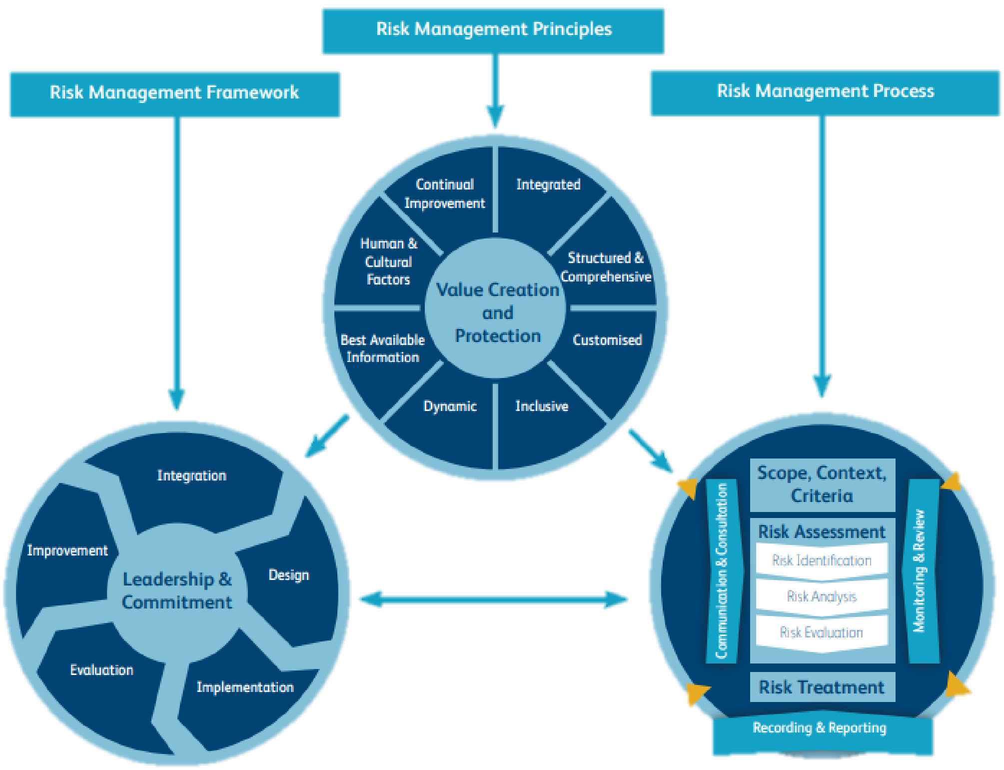

Figure 17 - ISO risk management principles, framework, and process (ISO, 2018)

Principles

The ISO 31000 guidelines provide a statement of risk management principles. The eight principles are described below:

1. Framework and processes should be customised and proportionate.
2. Appropriate and timely involvement of stakeholders is necessary.
3. Structured and comprehensive approach is required.
4. Risk management is an integral part of all organisational activities.
5. Risk management anticipates, detects, acknowledges and responds to changes.
6. Risk management explicitly considers any limitations of available information.
7. Human and cultural factors influence all aspects of risk management.
8. Risk management is continually improved through learning and experience.

The first five principles describe how to design a risk management initiative, and principles six, seven and eight are about how to use it. These latter principles support using the best information available, considering human and cultural factors, and making risk management arrangements that ensure continual improvement.

Framework

The purpose of the risk management framework is to help the organisation to integrate risk management into significant activities and functions. The effectiveness of risk management depends on it being integrated into the organisation's governance, including decision-making. This requires support from stakeholders, particularly top management.

Framework development includes integrating, designing, implementing, evaluating, and improving risk management across the organisation.

Process

The steps for risk management are:

- Establish the context: What is the scope for this piece of work, what area will it cover, what methodology will be employed, and who are the stakeholders? Who is responsible for managing risk, and who is at risk?
- Identify risks: What natural hazards could occur in our area of interest, what are the possible magnitudes, frequencies, extent and/or durations of these hazards?
- Analyse risks: What is the likelihood of hazard events of certain magnitudes occurring? What is exposed? What are the elements at risk, how vulnerable are they, how do we value them and what are the potential consequences of an event?
- Evaluate risks: Are the likelihood and consequences acceptable, tolerable, or intolerable? Which forms of risk treatment are available? To what degree will various risk treatments reduce the risk? Are there other benefits or negative outcomes of particular risk treatment methods? How much will risk treatments cost?

- Treat risks: Will the treatment be to avoid the risk, reduce the likelihood or consequences, transfer the risk, or accept the risk? What is the residual risk afterwards?
- Communicate and consult: Who is at risk? Who will pay for risk treatment? Do these stakeholders agree with the analysis and outcomes?
- Monitor and review: Do we need to revisit previous steps because of results or new information throughout the process? Is the residual risk acceptable?

A2 Auckland Council Toolbox

The following is taken from Auckland Council's Natural Hazard Risk Communication Toolbox (Auckland Council, 2014).

A natural hazard means 'any atmospheric or earth or water related occurrence (including earthquake, tsunami, erosion, volcanic and geothermal activity, landslip, subsidence, sedimentation, wind, drought, fire, or flooding), the action of which adversely affects or may adversely affect human life, property, the economy, or other aspects of the environment' (Resource Management Act, 1991). Together, these are often referred to as 'elements at risk'.

Risk is the 'likelihood and consequences of a hazard' (NZ CDEM Act, 2002). So, risk considers the consequences which the hazard may cause. 'Consequences' refers to an effect on the natural, economic, built or social environments as a result of the hazard. The consequences are influenced by how vulnerable the elements at risk are, by the exposure of elements at risk to the hazard, and by the characteristics of the hazard. Risk also accounts for the likelihood of the hazard occurring, which depends on the type of hazard.

A hazard is an event that is actually occurring, which affects human life, property, buildings, lifelines, or the economy. The level of hazard depends on the event characteristics. Natural hazards are often classified by:

- Magnitude – how large the event is in terms of energy produced (earthquakes, wildfire), volume (flood, volcanic ash), wind speed (storms), or material displaced (landslides, coastal erosion).
- Duration – how long the event lasts.
- Extent – the geographical area that will potentially be affected.
- Speed of onset – whether the onset will be a few seconds to a few hours (for example, earthquakes, local source tsunami, flash floods); a few hours to a few days (for example, storm winds, storm surge, frosts, river floods) or whether it will have a slow onset (for example, drought).

Risk refers to future events because in addition to considering the characteristics of the hazard and the potential consequences, we also consider the likelihood of a risk occurring.

To determine the level of risk, we need to consider:

- the natural event (for example, the duration and intensity of rainfall causing the flood, the potential water level increase, the extent of the area potentially affected).
- elements at risk in the area (for example, the number and locations of people, the cultural and economic value of the property and buildings, the location and type of infrastructure).
- the potential consequences of the flood on those areas, influenced by the characteristics listed in the above two bullet points, as well as the exposure and vulnerability:
    - exposure (for example, how long a person will be in the area, how long an asset will be exposed to the floodwater, and to what depth)

  - vulnerability (for example, how robust the infrastructure and buildings are, and how healthy and resilient the people in the area are).
- the likelihood of the event occurring (for example, how likely the river is to flood to a specific level or inundate a certain area).

If people in the area receive a warning and can evacuate before the rising floodwaters inundate the houses, their exposure, and so their risk, is low. Buildings are unlikely to be able to be moved in time, making their exposure to the flood high. The level of risk for these buildings depends on the flood characteristics and on the vulnerability of the buildings. Both the buildings and the people are affected by the same hazard, but their levels of risk are different.

A risk eventuates when elements (like human life and property) are vulnerable and exposed to a hazard. The level of risk can be described quantitatively (for example, in dollar losses or fatalities) or qualitatively (for example, as 'minor', 'moderate', or 'severe'), and includes the likelihood of a particular hazard event affecting elements at risk.

Risk is managed in a range of different ways. It is very rarely possible to eliminate all risk, so some potential consequences usually remain despite effective risk management. These potential losses or effects are called the 'residual risk'.

A3 Land use responses to levels of risk

In guidance produced for Queensland (QRA, 2012), land use responses for acceptable, tolerable, and intolerable levels of risk are provided. These include possible transition strategies, planning options, and land uses that may be appropriate for the given risk (see table below).

Table 18 - Queensland land use responses for levels of risk (QRA, 2012).

Land Use Responses and Possible Scheme Measures				
Planning Evaluation Risk Category	**Land Use Response* & Description** *** From table 7**	**Possible Land Use Transition Strategies**	**Possible Planning Scheme Options**	**Land Uses (QPP terms)** *** Consider relative to urban/rural location**
Intolerable Risk	**Retreat from specific existing urban areas** **Expand into new areas suitable for urban development** *The strongest land use response required to avoid risks to life or property. This would involve limiting land uses (e.g. 'back-zoning' in existing areas) and active measures to move people or property out of harms way*	• Actively limit future development in this area that may increase risk to life or property through strong zoning controls • Promote transition of at-risk existing uses & promote low-impact, non-urban uses • Discourage further intensification of existing uses • Implement built form improvements through application of Overlay Code for remaining land uses • Consider how to maintain community connectivity in areas to be transitioned • Also investigate complementary measures (e.g. voluntary purchase) to actively reduce existing at-risk people and property in this area • Also investigate structural controls to further reduce risk to life and property	Strategic Framework: • Intents/Outcomes limits development in these areas that would create unacceptable risk as per SPP1/03 policy Zoning: • Limited Development • Environmental Management • Conservation • Sport & Recreation • Open Space • Waterfront and Marine Industry • Rural • Flood-constrained Precincts as required (e.g. Residential Living – Flood Constrained Precinct) Overlay: • Built form controls	Appropriate (subject to assessment): Aquaculture Cropping Landing Market (temporary only) Outdoor Lighting Outdoor Sport and Recreation Park Permanent Plantations Port Services Waterfront and Marine Industry
Tolerable Risk (subject to ALARP)	**Adapt existing areas** **expand into new areas suitable for urban development** **Maintain agricultural and rural landscape values** *A considered approach to land use and urban design is required where a greater range of land uses may be appropriate than in areas of highest risk, but others generally remain inappropriate*	• Discourage sensitive land uses but permit majority of land uses • Use Precincts as transition zones for land use change over time • Density increases may be appropriate in line with good planning principles (e.g. TOD or infill development) - where strong emergency management, evacuation routes & early warning systems are available • Implement built form improvements through application of Overlay Code • Investigate improvements to transport/infrastructure linkages to improve resilience through PIP	Strategic Framework: Intents/Outcomes discourages incompatible land uses in these areas as per SPP1/03 policy Zoning: • Flood-constrained Precincts within all zones as required (e.g. Residential Living – Flood Constrained Precinct) Overlay: • Built form controls	Inappropriate: Child Care Centre Community Care Centre Community Residence Correctional Facility Educational Establishment Emergency Services High Impact Industry Hospital Intensive Animal Husbandry Intensive Horticulture Major Electricity Infrastructure Major Sport, Recreation and Entertainment Facility Medium Impact Industry Non-resident Workforce Accommodation Noxious and Hazardous Industry Relocatable Home Park Residential Care Facility Retirement Facility Substation Telecommunications Facility Tourist Park Appropriate: All other uses (subject to assessment)
Broadly Acceptable Risk	**Adapt existing areas** **Expand into new areas suitable for urban development** *Minimal land use changes required to respond to flood risk - urban design controls may be implemented to improve resilience*	• Broad consideration to be given to concern of flood – no specific strategy suggested • Land uses and density increases appropriate in line with good planning principles (e.g. TOD or infill development) - where strong emergency management, evacuation routes & early warning systems are available • Implement built form improvements through application of Overlay Code • Investigate improvements to transport/infrastructure linkages to improve resilience through PIP	Strategic Framework: • Intents/Outcomes support appropriate development in these areas Zoning: • No changes based on flooding concern Overlay: • Built form controls	Appropriate: All uses subject to appropriate built form controls being achieved

A4 HSE Tolerability of Risk Framework

The UK Health and Safety Executive (HSE) developed its own framework, known as the tolerability of risk (TOR) framework, to help with making decisions about risk. But HSE still notes that 'the factors and processes that ultimately decide whether a risk is unacceptable, tolerable, or broadly acceptable are dynamic in nature and are sometimes governed by the particular circumstances, time and environment in which the activity giving rise to the risk takes place' (HSE, 2001). Three sets of criteria can be used to assess risks:

- **Equity-based criteria** are based on the idea that all individuals have unconditional rights to certain levels of protection. In practice, this often means setting a maximum level of risk that individuals may be exposed to. Risks above this limit are considered unacceptable no matter the associated benefits.
- **Utility-based criteria** consider incremental benefits of risk reducing measures and their costs. Utility-based criteria compare—often in monetary terms—the relevant benefits (for example, statistical lives saved, life-years extended) with the net cost of adopting a particular risk prevention or reduction measure. A balance between the two must then be agreed.
- **Technology-based criteria** reflect the idea that implementing 'state of the art' control measures to control risks provides enough protection, regardless of the circumstances. These measures may be technological, managerial, or organisational.

Each of these criteria have relative strengths and shortcomings. The TOR Framework combines them all to provide flexibility, and to benefit from each approach's strengths while avoiding their disadvantages (HSE, 2001). The TOR Framework 'can in principle be applied to all hazards' (HSE, 2001), rather than only within the workplace health and safety setting. The TOR framework is shown in Figure 18.

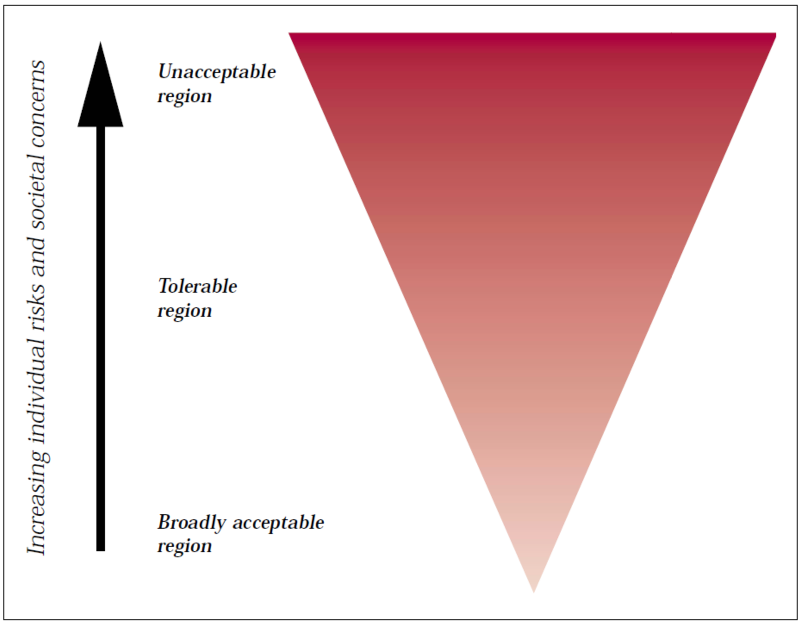

Figure 18 - HSE framework for the tolerability of risk (HSE, 2001)

The triangle represents increasing risk for a particular hazardous activity. This framework can be applied to either individual or societal risk. The TOR framework effectively uses equity-based criteria to assess risks falling in the upper region, and utility-based criteria for risks in the middle and lower regions. Technology-based criteria can be used throughout to complement the other approaches (HSE, 2001).

No explicit thresholds are given for each level or region. This allows for flexibility in approach, hazard, and circumstance. But assessing a risk mitigation or prevention measure's efficacy depends in part on where the boundaries between each region are. In some cases, levels of tolerability are prescribed (or implied) through legislation, approved codes of practice (ACOPs), industry guidance, or agreed 'best practice', making explicit TOR boundaries unnecessary. Still, HSE uses the following boundaries as guidance for the TOR Framework:

- 1 in 1,000,000 / 10^{-6} / 0.000001 / 0.0001%:
  the boundary between the 'broadly acceptable' and 'tolerable' regions for individual risk of death each year.
- 1 in 10,000 / 10^{-4} / 0.0001 / 0.01%:
  the boundary between the 'tolerable' and 'unacceptable' regions for individual risk of death each year **to the public**.
- 1 in 1,000 / 10^{-3} / 0.001 / 0.1%:
  the boundary between the 'tolerable' and 'unacceptable' regions for individual risk of death each year **to most workers**.

HSE (2001) also note that hazards with sufficiently high individual risk levels in the 'unacceptable' region of the TOR Framework often raise societal concerns. These concerns have a far greater influence in deciding the tolerability of a risk. Societal risk is considered through multiple fatalities occurring in a single event. HSE proposes the following boundaries as guidance for societal risks:

- 1 in 5,000 / $2x10^{-4}$ / 0.0002 / 0.02%:
  the frequency each year, above which the risk of an accident causing 50 or more deaths in a single event is regarded as 'intolerable' (the boundary between 'unacceptable' and 'tolerable' regions)

Again, noting that the factors that decide the level of risk are 'dynamic in nature and are sometimes governed by the particular circumstances, time and environment', HSE extends different TOR considerations to proposed and existing developments. This is because not allowing the risks to be taken on the first place (by not allowing a development) 'is relatively inexpensive when compared to the costs entailed in requiring existing developments with similar risks to introduce remedial measures' (HSE, 2001). This encourages the consideration of existing risks and exposure separately from the idea of increasing exposure and taking on more risk as a society. HSE uses the following boundaries for housing developments:

- 10 in 1,000,000 / 10^{-5} / 0.00001 / 0.001%:
  the individual risk of death each year to a hypothetical individual above which HSE advises against granting planning permission (the boundary between the 'unacceptable' and 'tolerable' regions)
- 1 in 1,000,000 / 10^{-4} / 0.0001 / 0.01%:
  the individual risk of death each year to a hypothetical individual below which HSE

advises against granting planning permission (the boundary between the ‘tolerable’ and ‘broadly acceptable’ regions)

The TOR Framework is ultimately intended to be used flexibly, and with common sense. Sometimes, there is no option that reduces the risks to a tolerable level, or certain activities that fall into the ‘intolerable’ region can be undertaken for a short period of time (like emergency services rescuing trapped people, or tramping trails passing through rockfall zones). The TOR Framework is perhaps the best-known example internationally of a framework for determining risk tolerance and thresholds. A significant number of regulators and industries well beyond its initial focus have accepted its underlying philosophy and approach (Holmes, 2000).

‘HSE believes that an individual risk of death of one in a million per annum for both workers and the public corresponds to a very low level of risk and should be used as a guideline for the boundary between the broadly acceptable and tolerable regions’ (HSE, 2001, p. 45).

A5 New Zealand adventure recreation activities

After the December 2019 eruption at Whakaari, MBIE consulted on its approach to keeping adventure activities safe in Aotearoa New Zealand. It is especially focused on reducing the risk of serious harm by managing risks relating to natural hazards. New Zealand's accident compensation system requires that adventure activities are regulated to ensure operators have some liability for their actions. The question is how to allow for activities that carry risk, while keeping risks at an acceptable level. MBIE states:

> *Different standards for acceptable risk apply in different situations. What is acceptable will be influenced by factors like who is being exposed to the risk, whether these people were fully aware of and chose to run the risk, and what the benefits are.*
>
> *In some situations, acceptable risk is decided according to a set calculation. For instance, some public health decisions (such as decisions on vaccines) consider risks to be acceptable where there is a less than one in one million chance of serious harm occurring. Similarly, some public safety decisions (such as allowing public access to hazardous areas) consider risks to be acceptable where there is a less than one in one hundred thousand chance of serious harm.*
>
> *We are not proposing settling on an exact calculation for what is acceptable risk in the adventure activities sector through this consultation process. However, we do need to work out what controls should be in place so that risks in adventure activities are kept at a level we, as society generally, consider to be acceptable.*

While the consultation document does not suggest thresholds for 'acceptable' or 'tolerable', some statements hint at thresholds. For example, again from (MBIE, 2021):

> *Natural hazards also present the main risk of catastrophic events (**single incidents that result in more than five deaths**) in the sector. Almost all natural hazards have some risk of causing catastrophic harm. While historical data is limited, there appears to be catastrophic (or near catastrophic) events involving natural hazards happening **at least every 10 years** in the adventure activities sector. Each of these events causes on **average eight fatalities and seven serious injuries*** [emphasis added].

So, once-in-ten-year events that cause more than five deaths seem to mark the threshold of 'intolerable'. This implies that the risk from these hazards should be reduced below this level. '*While it is not realistic to completely eliminate natural hazard risks in adventure activities, we think we can improve the system to reduce the level of risk and associated harm.'*

The consultation document suggests that MBIE regulate to ensure that the operators assess the risk they have from natural hazards and manage those risk that are intolerable. '…we propose introducing a specific regulation that makes it explicit that operators are required to do **all that is reasonably practicable** to assess and manage natural hazard risks that may affect their activities' [emphasis added].

The words 'reasonably practicable' present an issue here. These activities will come at a cost but will achieve some benefit in terms of risk reduction. This consultation process will hopefully clarify what is reasonable and practicable.

A6 Disaster risk financing

Two approaches to disaster risk financing are possible, the probabilistic and scenario approaches (OECD, 2015).

In the probabilistic approach, the full spectrum of potential disaster events and their respective probabilities are accounted for. In the scenario approach, specific disaster events are constructed to determine their potential impacts and spill-over effects. If risk is evaluated from a probabilistic perspective, it can be assessed and measured according to specific metrics, namely (OECD, 2015):

- Risk cost: Quantification of the expected AAL for the risk over a long period of time (the sum of each event loss multiplied by its respective probability of occurrence) measures the annualised risk cost and provides the basis for risk pricing; and,
- Probable maximum loss (PML): The maximum amount of loss expected to be incurred in a year with a given probability.

Knowledge of PML enables risks to be managed, for instance through risk transfer. These metrics enable a better understanding of disaster costs and scale of impacts and so promote more informed decision-making about financial strategies. Probabilistic risk assessment uses probability distributions to characterise the variability in risk estimates, as opposed to deterministic methods that are based on single-point estimates and discrete (stress case) scenarios (OECD, 2015).

Disaster risk financing (DRF) strategy is an important part of a comprehensive approach to disaster risk management and sustainable development. DRF should sit within an integrated framework of hazard identification, risk and vulnerability assessment, risk awareness and education, risk management, and disaster response and resilient recovery (OECD, 2017).

To design and implement targeted DRF strategies so populations can manage the financial consequences of disasters efficiently, assess:

- the expected financial effects of disasters on the economy, and
- the risk-bearing capacities of exposed populations and economic sectors (their capacity to absorb and recover from losses).

To identify possible financial vulnerabilities or financing gaps, evaluate:

- the scale and distribution of risks across the territory and major segments of the economy (including households, the corporate sector, the financial sector, and government – both central and local), and
- the financial capacities to absorb these risks.

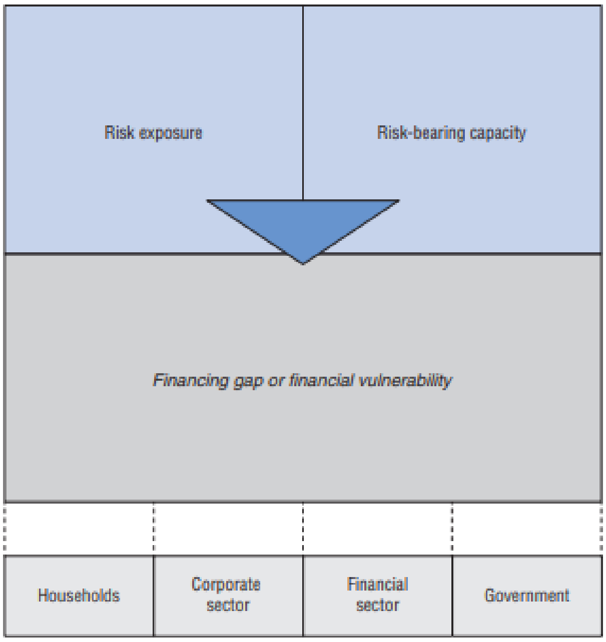

Figure 19 - Assessing disaster risk and financial vulnerabilities (OECD, 2015, p. 25)

Financial vulnerabilities exist when economic agents lack the resources to absorb and recover from losses in a major disaster, causing financial harm or economic disruption. These vulnerabilities can be addressed through:

- risk reduction measures (reducing risk exposure and disaster costs), or
- risk financing tools (securing post-disaster financial resources to meet disaster costs).

DRF strategies should aim to ensure there are adequate financial resources to meet the costs of the full potential range of disaster events. They should have an overall goal of strengthening financial resilience within the population and economy (see Figure 20). DRF objectives are achieved through resources or debt financing, risk financing tools such as reserves and insurance, and risk reduction. They are a critical component within broader DRM strategies aimed at reducing and managing risks, including through investing in risk prevention.

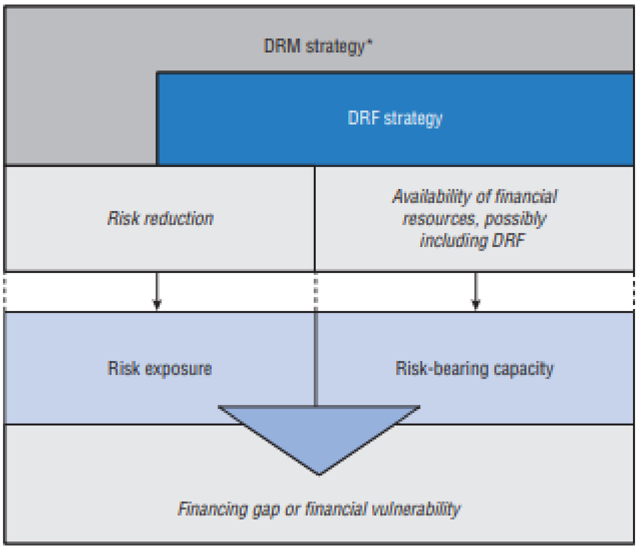

Figure 20 - Role of DRF strategies in strengthening financial resilience (OECD, 2015)

We can use the outcome of comprehensive risk assessments as a starting point to:

- determine the level of disaster risk exposure, and
- assess disaster-related financial vulnerabilities across the respective area and within the economy.

However, risk assessments should be accompanied by more details, comprehensive analysis of financial impacts and affected parties.

Te Kāwanatanga o Aotearoa
New Zealand Government

Toka Tū Ake EQC