Understanding How to Communicate Multi-hazard and Cascading Hazard and Risk Information to Aid Disaster Risk Planning

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Abstract

Driven by climate change, population growth, land use intensification, and an ever more interconnected world, disaster events are becoming more frequent, more severe, more costly, and more complex. As such, multi-hazard risk reduction, including robust data collection and decision-making, is increasingly important to ensure that the inevitable emergencies we respond to are less disastrous.

Nine professionals drawn from the Aotearoa New Zealand hazard and disaster 'risk reduction sector' (including technical specialists, emergency management professionals, and local and central government staff) were interviewed via semi-structured interviews to discuss their understanding and use of multi-hazard and cascading hazard and risk information for disaster risk reduction purposes. Professional context was found to be strongly influenced by the specificities of New Zealand legislation and the relationship between legislative requirements (including but not limited to the Resource Management Act 1991, Civil Defence Emergency Management Act 2002, Building Act 2004 and Local Government Act 2002).

These professionals use overlapping terms such as 'multi-hazard', 'cascading hazard' and 'compounding hazard', sometimes interchangeably, to describe a range of concepts, including the increasingly common situation where shocks or failures in one part of a system spill across to others. This complex interaction of potential risk, events, impacts and their conceptualisation presents a challenge for effective communication with and between decision-makers, the public, and peer organisations regarding disaster risk reduction. Consequently, consideration needs to be given to how to communicate such concepts so that they can be understood and used effectively in decision-making.

The interview findings suggest that narrative communication might be a possible solution. The merits of using narrative communication, in the context of risk communication, are discussed within this thesis. Narrative is recognised as a method of organising, understanding and communicating complex information, and is found to have potential as a frame for communicating multi and cascading hazard and risk information.

Additionally, guiding principles are proposed based on the results of the interviews to assist the development of more effective hazard model outputs and supporting communication products, recognising the power of a good story, well-designed graphics, and audience-appropriate scaffolding.

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1. Introduction

Aotearoa New Zealand is an island nation whose geography, climate, and historical patterns of human settlement present a range of natural and anthropogenic hazards, risks, and potential impacts. With steep hills and mountains thrusting up from the collision of two tectonic plates, areas of both potential and active volcanic activity, a significant capacity for extreme weather owing to its position in the heart of the southern Pacific Ocean, and numerous cities and critical infrastructure facilities sited in places with substantial exposure to those hazards, much of the country is under constant threat of potentially complex disaster events.

One of the most significant natural hazard threats is seismic activity. New Zealand is sometimes referred to as ‘the shaky isles’, and is a dynamic, shifting land that typically experiences about 20,000 earthquakes on average during any given year, with about 400 of those registering magnitude 4.0 or greater (Geonet, 2023). The South and North Islands that comprise the vast majority of the country’s land area have been formed by the convergence of the Australian and Pacific tectonic plates, and the collision and subduction of these plates generate immense tectonic stress, leading to frequent earthquakes along the country's various fault systems. The Alpine Fault, a major strike-slip fault running southwest-to-northeast through the South Island, is a seismic area where the Pacific and Australian Plates slide past each other, creating the spectacular Southern Alps mountain range. This fault has produced significant earthquakes in the past and is a persistent source of concern due to the potential for a major rupture. The Alpine Fault has not had a major rupture event in over 300 years but has been estimated to have a 75% probability of producing a major earthquake (with about a 4 in 5 chance of a magnitude of 8 or greater) within the next 50 years (Howarth et al., 2021).

Further north, the Pacific Plate is being subducted beneath the Australian Plate along the Hikurangi Trench, just off the east coast of the North Island, creating the Hikurangi Subduction Zone. This subduction can lead to the accumulation of stress over long periods, resulting in catastrophic releases of energy in the form of large earthquakes (Reyners, 1998). This subduction zone is similar in characteristics to that which caused the Tōhoku tsunami in Japan in 2011, and thus represents a similar significant tsunami risk to New Zealand (Wallace et al., 2016).

This subduction process has contributed to the formation of the North Island's volcanic features, such as the Taupō Volcanic Zone, which contains several active volcanic features. Auckland,

New Zealand's largest city, is established on the site of a volcanic field, and Taupō Moana is a 616 km^2 lake left over from one of the world's biggest supereruptions (Wilson et al., 1995).

New Zealand’s maritime climate, mountainous landscape, and its position exposed to Pacific weather patterns mean that it is also vulnerable to extreme weather, particularly intense rainfall and high winds. The west coast of the South Island is among the wettest places on earth (NIWA, 2023), and the capital Wellington is known as one of the windiest (Chappell, 2014).

In addition to this dynamic natural landscape, New Zealand (along with the rest of the planet) is facing uncertainties due to climate change, including sea level rise (which is expected to exacerbate impacts from existing ground movement in some coastal areas), and increased frequency and severity of weather and related events, including flooding, drought, and wildfire (Bodeker et al., 2022).

While Māori have lived in New Zealand for many hundreds if not a thousand years, significant increases in population and their associated land use intensification and construction of civil infrastructure have only occurred within approximately the last 180 years since the signing of the Treaty of Waitangi / Te Tiriti o Waitangi, which heralded a major influx of immigration from England and other European countries. As such, the locations and design of New Zealand’s current urban built environments and agricultural activities need to be appreciated as relatively recent modifications to the landscape. These changes in land use and development have also had the effect of reducing protective functions of natural systems, such as vegetation which attenuates flooding, or stabilises slopes, and dune systems which provide barriers against coastal storm surges etc. (Glavovic et al., 2010).

New Zealand has experienced significant natural disaster events of each of these types in the past. Much of the country’s area is still sparsely populated, with a population of about 5.2 million in a country covering an area of 268,021 km^2 resulting in an average population density of 19 people per km^2, but with 82% of the population concentrated in urban areas. Consequently, many if not most disaster events occur with minimal impact on human settlements (Statistics New Zealand, 2023; World Bank, 2023). However, numerous disasters have struck populated areas within recent memory.

Two recent earthquake sequences and events with significant impacts were the 2016 Kaikōura earthquake and the 2010–11 Canterbury earthquakes. The former caused only two fatalities but severed the country’s main north-south highway and rail connections, reshaped the coastline

due to uplift of the seabed, and caused structural damage to major buildings in the Wellington region (Dizhur et al., 2019). The latter Canterbury earthquakes devastated the central business district of Christchurch, the South Island's largest city, causing 188 fatalities, and radically affected the lives of those living there (Potter et al., 2015).

Volcanic eruptions are rarer, with centuries passing between eruptive events in many locations, but a few notable ones have had significant impacts. Most recently, the 2019 eruption on Whakaari/White Island killed 22 people visiting the island (Solomon, 2023). And while not directly caused by an eruption, the Tangiwai rail disaster of 1953, one of New Zealand's deadliest events, was caused by the collapse of a dam (created from ash-deposits of a prior volcanic eruption in 1945) of Mt. Ruapehu's crater lake, releasing a lahar that swept away a bridge just as a passenger train passed over it, killing 151 (Lecointre et al., 2004). The threat of major impacts to populated areas by volcanoes requires constant vigilance, as while these events are infrequent, the potential for destruction is massive (Dibble et al., 1985).

Storms and inundating rainfall are risks for much of the country, and severe flooding events occur frequently. Recent major flooding events include the East Coast of the North Island in 2023 (widespread devastation from Cyclone Gabrielle, including eleven fatalities), Auckland in 2023 (four fatalities, major infrastructure damage), Nelson in 2022 (hundreds of homes damaged), and Westport in 2021 (nearly four out of five homes impacted) (Kerr et al., 2023; Gadsden, 2023). Given the hilly steepness of much of the landscape of the country's populated areas, such events frequently trigger landslips which cause further damage, sever roads, and complicate response efforts; this was widespread in the recent Auckland and Nelson events. Occasionally, slips can be extremely significant in scale, as occurred in 1979 when a 5 million m^3 slip displaced 69 houses in the Dunedin suburb of Abbotsford (Hancox, 2008).

There have been issues in New Zealand with multiple hazards occurring during the context of a disaster event and situations with observed cascading events and impacts. For example, the Canterbury earthquakes brought not only ground shaking, but landslides that included huge boulders rolling into hillside houses. Those quakes also introduced the word 'liquefaction' into the New Zealand household vocabulary, a phenomenon where certain ground can act as liquid under intense ground shaking conditions (Quigley et al., 2013). In Christchurch's case, this caused significant amounts of housing and infrastructure to essentially sink. In 2023 Cyclone Gabrielle devastated significant areas on the east coast of New Zealand, causing landslides and flash flooding which took lives, damaged major infrastructure, knocked out power for weeks, and

disrupted food production resulting in increased produce prices around the country. This has sparked national level reflection on pre-existing conditions which may have led to worse outcomes, such as houses built on floodplains and forestry slash exacerbating flood damage (Harrington et al., 2023).

Given the potential for the aforementioned hazards to occur simultaneously or subsequently (as seen in Cyclone Gabrielle), it is more important than ever that we develop, use and effectively communicate information about multiple and cascading hazard risks. This information can be used to reduce devastating impacts before, during, and after future disaster events. Effective use of such information includes understanding how key users (people working within land use planning and management, emergency management, as well as the related policy level) both understand and use information about multiple and cascading hazard risks. The purpose of this research is to investigate how New Zealand practitioners understand and use multi-hazard and cascading hazard and risk information, and to explore how such information might be effectively communicated in ways that assist them with making and informing better disaster risk reduction decisions, before an event occurs.

1.1 Context for the research

This research was undertaken in collaboration with GNS Science Te Pū Ao (GNS) from 2022-2023 to fulfil the thesis requirement for a Master of Emergency Management degree with the Massey University/GNS Science Joint Centre for Disaster Research in Aotearoa New Zealand.

GNS is a New Zealand Crown Research Institute that undertakes research to increase Aotearoa New Zealand's resilience to natural hazards risk. This social science qualitative research project was designed to support ongoing GNS research on modelling multi-hazards and cascading hazards by investigating communication considerations around the use of multi and cascading hazard and risk information in the current New Zealand professional environment. The aim of the work is to provide insight into how hazard and risk communication approaches can enhance decision-making in the pre-event disaster risk reduction and readiness phases, to minimise impacts experienced in the disaster response and recovery phases.

Specifically, this research takes a deeper dive into the perspectives and experiences of nine New Zealand professionals working around the country in both local and central government roles, who use or require multi or cascading hazard and risk information in the context of their daily work. This included gathering information about their professional contexts and decision-making processes and working through a set of structured questions using two examples of

multi or cascading hazard and risk visual communication products as discussion prompts, with a particular focus on their experiences using narrative communication approaches.

1.2 Research questions and objectives

The primary research questions for this project include:

1) How do New Zealand practitioners understand and use multi-hazard and cascading hazard and risk information for disaster risk reduction purposes?

2) How can multi-hazard and cascading hazard and risk information be effectively communicated to aid disaster risk reduction decisions?

The objectives sought from this research project were as follows:

- To review how multi and cascading hazards are interpreted by professionals, drawing on behavioural and risk science discourse and specifically understand how participants define the terms ‘multi-hazard’ and ‘cascading hazard’,

- To understand the context of the professional roles of participants and identify what decisions need to be made based on multi-hazard and cascading hazard or risk information,

- To specifically explore the application of narrative communication as a risk communication tool for non-technical decision makers,

- To explore practitioners’ perceptions of barriers and opportunities in relation to considering multi-hazard and cascading hazard and risk information in their practice,

- Considering decision-making contexts, to explore how multi-hazard and cascading hazard and risk information might be best communicated to practitioners, and

- To develop communication recommendations for multi-hazard and cascading hazard and risk technical output products.

1.3 Risk reduction context in New Zealand

To understand risk reduction in New Zealand, and thus the setting in which multi and cascading hazard and risk information might be used by risk reduction professionals, I provide an overview of the ‘disaster risk reduction sector’ in New Zealand, which is a conceptual frame that spans a range of functions and disciplines, rather than being a distinct field of professional practice.

Practitioners in this sector are concentrated across different levels of government, working in roles related to hazard and disaster risk reduction. These roles include emergency management, land use planning, technical and specialist science advisory, and other functions of local and central government, including policy and regulatory areas.

The disaster risk reduction context in New Zealand needs to be viewed through the lens of relevant legislation and associated policies. The primary statutes which constitute the New Zealand disaster risk reduction sector include the Resource Management Act 1991 (RMA), the Civil Defence and Emergency Management Act 2002 (CDEM Act), the Local Government Act 2002 (LGA), and the Building Act 2004. These statutes have been supported by national policy statements and standards which relate to specific hazards.

1.3.1 Resource Management Act 1991

The RMA is the primary piece of legislation that governs how decisions are made about the use and development of natural and physical resources in New Zealand. It provides a framework for land use planning, with specific provisions for regulation and management of land use and development in areas prone to natural hazards (Resource Management Act 1991). It requires local authorities (regional, district and city councils) to establish systems and processes to assess potential risks of natural hazards (e.g. flooding, coastal erosion, landslides, earthquakes, etc.) as part of their land use and development decisions, including considering the effects of climate change. This assessment involves identifying hazards, evaluating their likelihood and consequences, and determining the appropriate level of risk management required to minimise risk of harm to people, property, and the environment, which are captured in statutory district and regional plans. The negotiation of an appropriate level of natural hazard risk management is largely incorporated into hazard management considerations in regional policy statements and district plans (which must include policies and rules that regulate development in hazard-prone areas, such as floodplains, coastal areas, and unstable slopes). While the RMA allows decisions to be made regarding 'existing uses' of property to manage changing risk profiles, RMA land use planning decisions have largely focused on reducing risks associated with future development. There has been less clearly established professional practice around how to use the RMA to reduce risks to existing development (Grace et al., 2019), and attempts made by Councils to use risk-based approaches to manage natural hazard risks have been described as ad-hoc with varying degrees of success (Tonkin & Taylor, 2016).

Central government can issue national policy statements, national environmental standards, and national planning standards as instruments in respect of the RMA. The National Policy Statement on Urban Development 2020 (NPS-UD) is one such instrument which relates to risk reduction as it directs local authorities to undertake more collaborative long-term planning and to identify where development growth should be encouraged and where it should be constrained. However, while the NPS-UD encourages some consideration of hazards in the context of development constraints, it mainly represents a 'system tweak' to land use planning settings for the purposes of encouraging and enabling growth in a constrained housing market.

As of November 2023, there is a proposed National Policy Statement for Natural Hazard Decision-Making out for public consultation. The intent of this policy statement is to provide direction to decision-makers regarding appropriate weight to attach to natural hazard risks in RMA decision making. The discussion document for the draft policy statement acknowledges that the RMA does not provide enough direction relating to natural hazard risk in terms of planning, including data gathering, mapping, how to manage risk and how to develop rules which has led to inconsistent and ad-hoc regional approaches (Ministry for the Environment, 2023). There is also a view that capability and capacity need an uplift, particularly at local government level. Infrastructure New Zealand's (2023) submission on the proposed National Policy Statement on Natural Hazard Decision-Making discussion document takes the position that clear and consistent guidance from central government, greatly improved data stewardship, and resources for local government are required to improve risk identification, mitigation, and management, and ensure that the public understands the increasing risks of natural hazards and disasters. A consistent national framework for identifying and addressing natural hazards is signalled in the discussion document as a priority to be developed over the next one to two years.

It has been widely accepted that the RMA framework has presented challenges for effective natural hazard risk mitigation at the local government level for several reasons, particularly in areas which are already developed (Resource Management Review Panel, 2020). The framework is too static, it does not easily enable consideration of changing risk, particularly in the context of climate change (Lawrence et al., 2021), and it does not enable an ability to respond quickly to new information (Saunders & Kelly, 2021). Subsequently, the New Zealand government committed to reforming the RMA system to address issues in relation to environmental protections; population growth; strategic resource allocation; climate change response considerations, as well as to improve its effectiveness in managing natural hazards

and reducing disaster risks. As of writing, the outgoing New Zealand government started the process to replace the RMA with three separate pieces of legislation: the Natural and Built Environments Act (NBEA), the Spatial Planning Act (SPA) and the Climate Adaptation Act (CAA) (Ministry for the Environment, 2020). Collectively, it had been envisaged that this would create a land use system with an enhanced ability to protect and restore the environment, while allowing for the right developments in the right places and providing greater awareness around the impacts and management options for climate adaptation (including who pays). In August 2023, the first two pieces of legislation, the NBEA and the SPA were passed into law; however, the incoming New Zealand government has made election pledges to repeal these statutes and replace them with an alternative RMA (New Zealand National Party, 2023).

Reform of the RMA is likely to have a significant impact on the management of natural hazards and reduction of disaster risk in New Zealand. As described in the discussion document for the draft National Policy Statement on Natural Hazard Decision-Making, agreed parameters for assessing and managing natural hazard risk still need to be established and further exploration of the current state is a focus for this research (MFE, 2023). Local authorities have been developing and refining approaches for incorporating multi and cascading hazard and risk information into regional and district plans, and the availability of hazard and risk information has been increasing; however, currently there is no specific guidance for how hazard mapping should be undertaken or used, and thus established practice is regionally variable (Saunders & Kelly, 2021). Addressing standards for multi and cascading hazard and risk approaches could allow a capability uplift (e.g. shared understanding of best practice assessment methodology, policy wording, mapping). More clarity at the national level could significantly improve the consistency and effectiveness of integrating multi and cascading hazard and risk information into planning processes and associated statutory plans, including clear expectations around appropriate usage of such information, particularly in situations where developments already exist.

1.3.2 Civil Defence and Emergency Management Act 2002

The legislation which most explicitly deals with the management of disasters in New Zealand is the CDEM Act (Civil Defence Emergency Management Act 2002). The CDEM Act outlines the powers and decision-making functions within declared states of emergency, and it also establishes the framework for how central and local government, emergency services and other agencies work together. This includes the development of plans and procedures for emergency

response, preparedness training, and the provision of public education and awareness about disaster risks and emergency preparedness more generally. The CDEM Act also sets out provision for a range of supporting statutory documents, including the National Civil Defence Emergency Management Plan (setting out roles and responsibilities); Director's Guidelines (guidance and advice on how the legislative functions should be performed); and the National Civil Defence Emergency Management Strategy (outlining vision and long-term goals for emergency management; renamed the National Disaster Resilience Strategy as of 2019).

The stated purpose of the Act is to provide for the effective and efficient management of emergencies and to reduce the risk of emergencies occurring (CDEM Act 2002). The '4 Rs' of emergency management in New Zealand include risk reduction, readiness, disaster response and recovery. In terms of risk reduction, the focus of this research, the CDEM Act has a stated purpose to encourage and enable communities to achieve acceptable levels of risk (broadly encompassing risk identifying, assessing, managing, consulting, communicating, etc.). Therefore, the CDEM Act and its associated structures have a mandate to support how multi and cascading hazard information is understood and applied to reduce risk. However, in practice emergency management practitioners and functions have largely been perceived as only serving an emergency response function. Integration with wider natural hazards functions within councils has relied on 'influential personalities' rather than any embedded system settings (Crawford et al., 2018b).

The CDEM Act is also currently being reformed. The replacement Emergency Management Bill was introduced into parliament in June 2023, has passed its first reading and as of November 2023 is sitting at the select committee stage, having just closed for submissions (National Emergency Management Agency, 2023). The proposed Emergency Management Bill is not intended to represent a fundamental change to the legal framework established under the CDEM Act. It does not propose a change to established emergency powers, but primarily seeks to clarify roles, responsibilities and specific functions of people and entities during disasters e.g. government agencies, local authorities, emergency management centres (replacing CDEM groups). It also provides for greater provision for the role of Māori and recognition of Te Tiriti o Waitangi, more explicit directive for critical infrastructure planning, and enhanced community engagement expectations.

1.3.3 Local Government Act 2002

The LGA provides an understanding of the context and role of local government in New Zealand and how councils work with each other, with central government, and with their communities. The LGA outlines roles, responsibilities and powers of regional councils and territorial authorities (district and city councils). It requires local government to carry out services regarding the avoidance and mitigation of natural hazards, and to produce long term plans in collaboration with their communities, which provide details and costs of council activities (Local Government Act 2002). Councils are required to be open and transparent with the community about information and consult on plans, activities, and costs to ensure appropriate hazard mitigation activity is being undertaken. Access to, and understanding of, multi and cascading hazard information is required to support these activities; however, there is no standardised requirement or guidance for how this should be done and Councils have different approaches. The Local Government Official Information and Meetings Act (1987), which is the legislation that specifically provides for how people can access information from local government, was amended in 2023 to be more directive about natural hazard related information to be included in land information memoranda ('LIM reports', commonly obtained when purchasing property). It also includes the requirement that a LIM report must not only disclose hazard information, but information relating to "cumulative or combined effects of the hazards" on the land concerned. This represents a new statutory requirement on Local Government to consider and disclose information about the interplay between multiple hazards; however, there is no specific guidance for how to do this.

1.3.4 Building Act 2004

The Building Act 2004 is the statute which sets out the regulatory framework for the construction and ongoing maintenance of buildings in New Zealand, with specific requirements for mitigating the effects of natural hazards. The Act includes provisions to ensure that buildings are designed, constructed, and maintained to reduce the risk of harm to people, property, and the environment in the event of a natural hazard (Building Act 2004). The Ministry for Business, Innovation and Employment (MBIE) acts as the regulator who 'maintains' the regulatory system, and local authorities implement the system by directly issuing and approving building consents to ensure that buildings are constructed in accordance with the New Zealand Building Code. The Building Code includes detailed technical specifications and specific requirements for managing the effects of natural hazards, such as earthquakes, wind, and flooding (depending

on where development is located, and relevant district plan hazard provisions). Code Compliance Certificates for building consents are only issued after a thorough local council assessment of design and construction methodology. The Building Act also places requirements upon building owners to ensure their buildings continue to perform to a certain standard, including addressing any damage caused by natural hazards (Building Act 2004). To assess if the Building Code itself is effectively mitigating the effects of natural hazards, a high level of information about the natural hazard risk, including the potential cumulative or combined effects of hazards, as mentioned above, is required.

1.3.5 Other legislation

The Climate Change Response (Zero Carbon Amendment) Act 2019 set in motion a new strategic architecture for New Zealand, which now mandates regular 6-yearly national climate change risk assessments. An associated New Zealand National Adaptation Plan (NAP) is required to articulate how the country will collaboratively respond to identified and prioritised climate risks (Climate Change Response (Zero Carbon) Amendment Act 2019).

The first New Zealand National Climate Change Risk Assessment (New Zealand Ministry for the Environment, 2020) painted a stark picture of the extreme and critical risks that climate change creates for New Zealand, on top of the existing dynamic hazardscape discussed in Section 1.1. There is an increasing overlap and interrelation between 'general' disaster risk reduction activity and specific climate adaptation efforts, and the latter has been drawing increasing attention as the country responds to and recovers from extreme weather events. The NAP outlines several key actions to support the availability and use of multi and cascading hazard and risk information, including a National Emergency Management Agency (NEMA) action to "improve how science, data and knowledge are used to inform emergency management". This anticipates that by 2024, "science, data and knowledge of natural hazards and risks, including their inter-relationships with climate, are increasingly shared across all parts of the emergency management system" (New Zealand Ministry for the Environment, 2022, p.9). Reform of the RMA and the CDEM Act, as well as the implementation of the National Disaster Resilience Strategy are also all captured as actions within the first NAP (New Zealand Ministry for the Environment, 2022). Implementation of the NAP actions will be monitored and reported on by the independent Climate Change Commission. This may help to elevate the visibility of individual actions described in the NAP, including potentially elevating the aspirations outlined in the National Disaster Resilience Strategy, which was published in 2019 but appears to have had

relatively limited attention and resources provided for its implementation to date (New Zealand Ministry of Civil Defence & Emergency Management, 2019).

Looking across the RMA, the CDEM Act, the LGA and the Building Act, there is a lack of consistency in considering hazard and risk which creates wide scope for practical interpretations when it comes to considering how to effectively apply multi and cascading hazard and risk information. This likely creates a challenging environment for risk reduction practitioners as they navigate the complexities associated with supporting decision-making in respect of their responsibilities described in the above legislation. This research project sought to further explore the experiences of practitioners working within this context.

1.4 Multi and cascading hazard and risk context in New Zealand

'Multi' or multiple hazard in international disaster risk reduction discourse generally refers to the multiple potential hazards that a place faces, and situations where hazard related events (and impacts) may occur, either simultaneously, cascadingly or cumulatively (UNDRR, 2017). Cascading hazards therefore represent a subset of multiple hazard and focus on cascading hazards and potential impacts is a growing area of discussion within the disaster risk reduction field as well as within climate change and climate change adaptation research. Cascading impacts are understood to be the complex and multidimensional results of hazard events and are increasingly understood in terms of vulnerability of places and systems (IPCC, 2022). Further discussion around definitions and use of the terms multi and cascading hazards is provided in Chapter Three.

Consideration of multi and cascading hazards, the risks they present, and their potential impacts are important in the New Zealand context. They must be considered to reduce the many risks presented by the New Zealand hazardscape, to prepare and adapt for a changing climate, and to meet the stated aims captured across the relevant risk reduction legislation described above. There is an increasing amount of hazard information available; however, less is known about the complexities associated with responses to hazard events, and how these actions interact and impact overall risk (Simpson et al., 2023). The potential emerging requirement for regional spatial strategies under the replacement framework for the RMA may offer new opportunities for regionally consistent spatial approaches for considering multi and cascading hazard risk and ways to ensure future event responses are cognisant of the complexities of the wider riskscape (SPA, 2023). At the time of writing in November 2023, the incoming government has committed

to repealing this legislation, however it is unclear if a strategic spatial planning component will be present in any new RMA replacement legislation (New Zealand National Party, 2023).

In New Zealand, critical information for assessing multi and cascading hazard and risk primarily emanates from agencies and organisations with designated research and data mandates. Crown Research Institutes, such as GNS Science Te Pū Ao (focused on geological and earth-system processes) and NIWA Taihoro Nukurangi (focused on climate and the atmosphere) provide research that increases New Zealand's resilience to natural, weather, and climate hazards. Crown Entities like Toka Tū Ake EQC (investing in natural disaster research and providing insurance), State-Owned Enterprises such as Metservice Te Ratonga Tirorangi (the national weather authority), and various independent research organisations, private consultancies, and universities play pivotal roles in providing this information.

These entities offer their insights in different formats, including but not limited to: online portals, such as Riskscape.org.nz (an open-source spatial data processing application used for multi-hazard risk analysis), GNS databases, such as the New Zealand Volcano Database, NIWA climate change projections, research reports, and summary publications and programmes such as the National Science Challenge Deep South Challenge, as well as consultant reports and modelling, e.g. floodmaps (Crawford et al., 2018a; Lawrence at al., 2020; Robson, 2021). Professionals in the risk reduction sector are the primary consumers of this information, utilising it for specific functions in relation to their statutory mandates, e.g. land use planning related activities, such as creating hazard map layers within district plans; mapping evacuation areas for emergency scenarios, such as tsunami; informing community discussions about hazard and risk generally etc. However, it has been observed that existing hazard risk outputs are not always readily accessible for a wider community-based audience (Auliagisni et al., 2022).

This research project sought to further understand how New Zealand practitioners were using and communicating multi and cascading hazard information, including their current use of visual communication products, and what could be learnt from their experiences to inform approaches to communicate increasingly complex hazard information and more detailed model quantifications of hazard risk. The participants interviewed for this research were drawn from a range of roles across the risk reduction and were shown examples of different types of hazard and risk communication visual products to facilitate discussion, as further described in the following chapter on Research Methodology.

1.5 Summary

New Zealand's dynamic geography and climate make it susceptible to a wide range of natural hazards, including earthquakes, volcanic eruptions, extreme weather events, and landslides. Increases in population, land use intensification, and climate change has increased the potential for adverse outcomes. There is a growing recognition of the importance of multi and cascading hazard and risk information for better decision-making; however, the existing legislative framework for managing natural hazards is complex and inconsistent, which can create challenges for risk reduction practitioners.

This research project sought to explore how New Zealand practitioners understand and use multi and cascading hazard and risk information and identify opportunities to improve communication strategies. The following Research Methodology chapter describes the approach taken, including: 1) a comprehensive literature review to gain a theoretical understanding of the nature of multi and cascading hazard and risk information and its interpretation and use, and 2) semi-structured interviews with professionals to delve into their practical experiences and perspectives. By bridging these theoretical and practical insights, the research seeks to contribute to the development and communication of effective multi and cascading hazard and risk information, ultimately leading to improved risk reduction outcomes for New Zealand.

2. Research methodology

2.1 Introduction

This chapter introduces the theory and method of data collection, analysis and interpretation used to examine perspectives and experiences of professionals around the use and communication of multi or cascading hazard and risk information in the context of their work. It is anticipated that insights gathered can be used to inform future communication considerations for multi or cascading hazard technical outputs.

This was a social science qualitative research project using grounded theory methodology as the basis of the approach to explore the research questions outlined in Chapter One. In alignment with fundamental considerations for research design outlined by Creswell & Creswell (2018), a qualitative approach using grounded theory methodology was selected based on the nature of the research questions being addressed, in this case a strong focus on practitioner perceptions, with particular consideration of the audiences for the study—a diverse range of practitioners themselves.

Grounded theory methodology is a well-established qualitative research approach that encourages the gathering of rich data which can reveal participants' views, feelings, intentions, actions as well as details around the specific contexts of people's lives (Charmaz, 2014). The methodology follows guidelines including sampling, theoretical saturation, constant comparison, coding, sorting, and use of memos, with the aim being to systematically collect and analyse data to iteratively construct a theory that is grounded in the data collected (Niasse, 2023). Some researchers follow purist grounded theory principles, conducting data collection without a pre-data literature review to maintain objectivity and avoid data contamination (El Hussein et al., 2017). This approach prioritises discovery over verification but faces criticism for neglecting the understanding of existing research discourse and the context of one's research focus (Bryant & Charmaz, 2007).

Grounded theory was selected for this research as it prioritised discovery in a way that allowed for nuance and contextually rich understandings to emerge given the diverse range of participants grappling with an increasingly important but loosely defined aspect of their roles. The approach sought to strike a balance between pure theory induction and theory-guidance. As the data collection involved interviews with professionals supporting specific statutory functions within the New Zealand context, it was necessary to undertake preliminary literature

review specific to the New Zealand context to ensure questions posed were appropriate, understand lines of discussion during the semi-structured interviews, and assess the significance of the insights shared by participants. However, the substantive literature review was undertaken post data collection and occurred concurrently with the analysis phase. In this way, the grounded theory methodology was adapted to be sensitive to the context of undertaking interviews allowing for open reflection with New Zealand professionals working in specific technical settings (Charmaz, 2014).

The research comprised the following stages which are outlined in this chapter in further detail:

- Literature review
- Interviews
    - Participant selection
    - Interview questions
    - Discussion materials
    - Ethics approval
    - Data collection and transcription
- Data analysis
    - Coding
- Findings interpretation and development recommendations

2.2 Literature review

The literature review for this research project was initiated prior to refining the research questions and undertaking interviews, it informed the interview questions and discussion materials, and it was then iterated concurrently with the data analysis and recommendation development process. In alignment with best practice for grounded theory, the literature was approached with an open mind to inform theoretical ideas rather than guide the research process itself (Charmaz, 2014).

When undertaking research using a grounded theory methodology, the approach to conducting a literature review differs from other methodologies, which utilise a literature review to identify gaps that require further research. Grounded theory focuses on generating theory from data gathered via the research process, rather than explicitly testing existing theories (Charmaz, 2014). This approach was developed and established in the late 1960s and has become one of the most influential interpretive research styles, allowing for research results to be elaborated for their meaning and thus potentially establishing theoretical insights (Strübing, 2019).

The literature review was initiated by examining what is known about perceptions of risk generally, drawing on behavioural and risk science discourse; the use of terminology around

multi and cascading hazards; what this means for how practitioners understand and interpret multi and cascading hazards and risks; as well as an exploration of communication of hazards and risk, with specific emphasis on narrative communication. This allowed for the development of a base understanding of the core concepts within current research as well as the ability to draw connections between risk perception discourse, current understandings of multi and cascading hazard terminology, and concepts of narrative communication and associated approaches.

Literature was identified primarily using the Massey University Library, drawing from a range of databases for articles, academic journals, and other repositories, e.g. ScienceDirect, SageJournals, SpringerLink, Taylor & Francis Online, Wiley Online Library and others, with supporting material drawn from Google Scholar database. New Zealand government websites were also identified as the primary source for New Zealand public sector reports, information, and legislation. Searches were conducted using keywords that relate to the core areas of risk perception, multi or cascading hazards, risk communication and narrative communication. Key authors identified then formed the basis for further searches relating to their wider related research. Literature was identified in the form of practical textbook guides, government reports and strategy documents, journal articles, individual chapters within edited texts and professional guidance materials. Identified literature was logged using Zotero academic software, which allows for organisation and annotation of primary source material. Abstracts were reviewed for their relevance; literature assessed to be most relevant was annotated within Zotero with additional notes grouped around the general themes of risk perception and bias; definitions and concepts for multi and cascading hazards; narrative communication; risk communication, and visual communication. These themes then formed the core basis of the literature review.

The knowledge gained through the literature review was revisited throughout the interview data analysis stage as interview findings highlighted specific conceptual understandings in relation to multi-hazard and cascading hazard terminology as well as participants' reflections in relation to their professional experiences with communicating risk information. The findings from the literature review are outlined in Chapter Three. Literature review findings did not heavily influence the initial structure of the interview questions nor the discussion materials, which were kept intentionally broad and separate to align with a grounded theory discovery approach; however, early literature reviewed in relation to narrative communication did inform the inclusion of a question in relation to participants' roles. Literature review and interview findings were brought together and further explored after data gathering.

2.3 Interviews

Interviews were used as the primary source of data for this research. Interviews are a technique used within qualitative research to gather rich and in-depth data by directly interacting with research participants (Berg & Lune, 2017). A grounded theory approach to interviews typically involves using interviews as the primary method of generating data to inform a theory, which is grounded in the experiences and perspectives of the interview participants themselves (Charmaz, 2014).

The interviews conducted for this research were carried out using a semi-structured or open-ended approach. This is an interview style where the interviewer has a general outline or set of broad questions to guide the interview but allows flexibility for participants to provide detailed responses and explore their perspectives more deeply (Rubin & Rubin, 2012). The approach used an open-ended set of questions, with supporting visual communication materials introduced in the second half of the interview, creating a rich environment for participants to share their own relevant experiences using and communicating multi hazard and cascading hazard and risk information. Interviews were conducted virtually and digitally recorded using Microsoft Teams, then transcribed, coded, and analysed using the grounded theory approach described below.

2.3.1 Participant selection

Nine interviewees were identified and selected for this research based on their current roles as practitioners working within the New Zealand disaster risk reduction sector. Recruitment began in June 2022, with interviews being conducted from October-November 2022. Recruiting interviewees for qualitative research involves various techniques to identify and select individuals to ensure valuable insights. The techniques used for this research involved purposive sampling followed by snowball sampling. Purposive sampling involves deliberately selecting participants based on specific criteria related to the research aims (Guest et al., 2006), and snowball sampling is a deliberate technique where respondents are identified who are then used to refer researchers on to further respondents (Atkinson & Flint, 2001). An initial shortlist of potential interview participants was determined in collaboration with GNS Science, who were able to identify key stakeholders that they had worked with previously in the context of multi-hazard impacts analysis. This list was then cross-referenced with the specific criteria for subject selection for this project.

The criteria for subject selection included New Zealand based practitioners working in the following specific professional areas:

- Natural hazards
- Land use planning
- Risk reduction or climate change adaptation
- Asset Management/Infrastructure
- Emergency management.

Interviewees were recruited via an email invitation using professional networks and selected to ensure a broad spread of professional contexts and locations. Interviewees contacted were able to provide further referrals to other colleagues, which resulted in a national distribution of participants. Interviewees represented both national and local government organisations and were spread throughout the regions, including Auckland, Thames-Coromandel, Bay of Plenty, Wellington, Hawke's Bay and Canterbury.

Interviewees worked for the following organisations:

- Auckland Emergency Management
- Bay of Plenty Regional Council
- Canterbury Civil Defence Emergency Management Group
- Environment Canterbury
- Greater Wellington Regional Council
- Hawke's Bay Civil Defence Emergency Management Group
- Ministry of Business, Innovation and Employment (MBIE)
- Thames-Coromandel District Council
- Toka Tū Ake EQC.

All interviewees volunteered their time and were not compensated for their participation.

2.3.2 Interview questions

An open-ended set of interview questions was developed based on the initial literature review. The interviews were then conducted using a semi-structured approach, allowing participants to

elaborate using examples from their own experiences. A full list of questions is attached in Appendix A.

The framing of interview questions was kept broad and open, in alignment with the research objectives. Narrative communication concepts from the initial literature review informed the specific inclusion of the question asking participants to describe where they worked and their role within the systems of their work. This allowed participants to place themselves within the context of the emergency management or land use management system and relevant legislation. Further prompts were used for the types of decisions they made and influenced in the context of hazard, risk, and impacts. This allowed participants to introduce and describe themselves in terms of who they are and what they do within the risk reduction systems that they operate, before elaborating on how they use information. In this way, a deeper appreciation of participants as both audience and actors within the story of their work contexts was possible, which allowed for deeper understanding of their experiences and perspectives.

All participants were asked to articulate their understanding of the terms ‘multi-hazard’ and ‘cascading hazard’ respectively, and prompts were included to ensure an explicit articulation of each term or concept. This question was designed to understand how participants understood and used this language in New Zealand and how this aligned with the research literature, and the concepts as described within New Zealand legislation.

Further questions were then asked to describe how multi or cascading hazard information was applied to their work; what kinds of hazard or information was required for decision-making; and barriers that have been experienced in terms of incorporating multi or cascading hazard risk information into their work.

2.3.3 Discussion materials

Two visual examples were used as discussion prompts in the second half of the interviews, introduced as examples of different ways to communicate multi and cascading hazard or risk information. The visual examples used are included below (Figures 1 and 2). Participants were asked to reflect on these New Zealand-based examples and then share their perspectives on modes of communication for complex hazard or risk data—which is of relevance to multi and cascading hazards.

The first example (Figure 1) was a visual diagram illustrating an example of cascading hazards, developed in the context of a specific scenario (an earthquake and aftershock sequence, plus

storm event) for planning purposes (Orchiston et al., 2016). This visual example was chosen as it specifically highlighted the relationships between geomorphic phenomena, introduced additional situational complexity, and included a temporal aspect (short term, immediate and prolonged, long term).

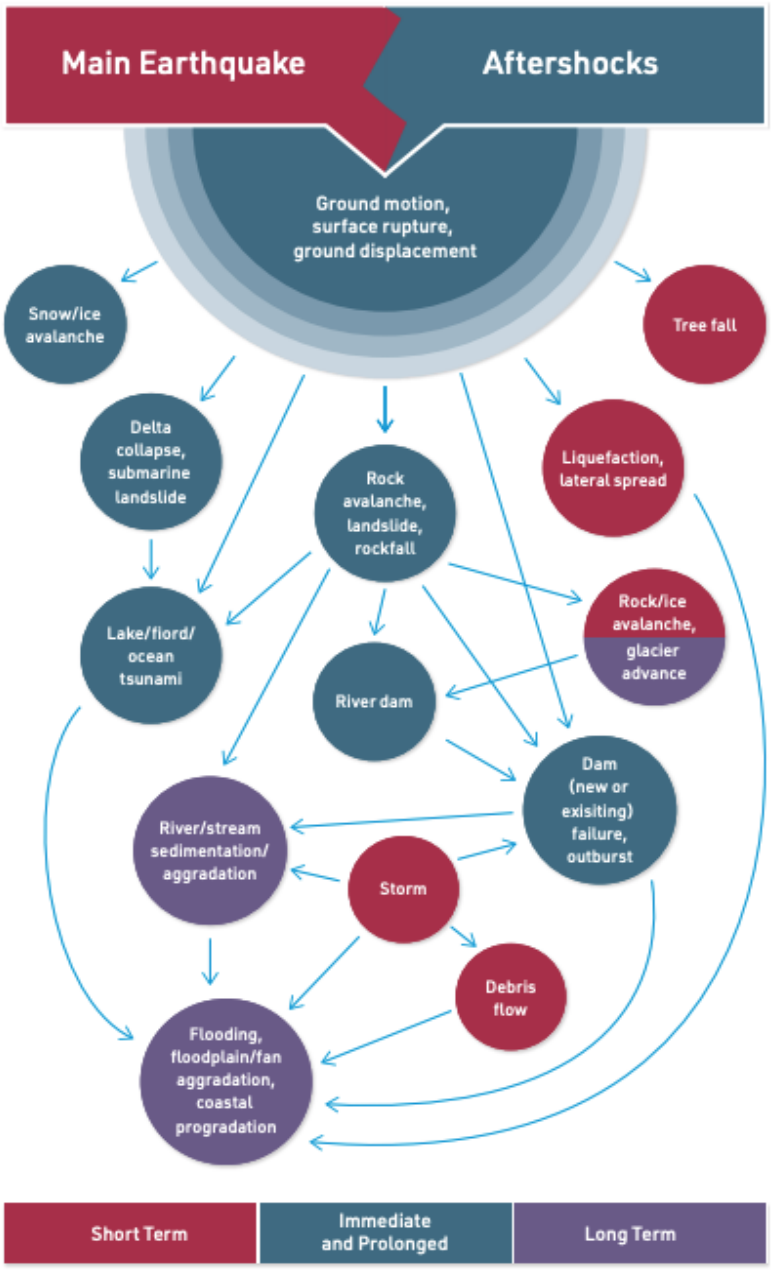

Figure 6: The range of geomorphic phenomena triggered by a major earthquake sequence, and their relationship cascade. The earthquake sequence and subsequent storms provide the drivers, and are shown in the boxes with thick black outline. The longevity of each resulting phenomenon is indicated by colour.

Figure 1: Interview example one (AF8 relationship cascade)

The second example (Figure 2) was showing a simulated outage map for a New Zealand based wastewater network (Uma et al., 2021). This example was chosen as it represented a single impact hazard based scenario and focused on multiple spatial and temporal impacts for planning purposes.

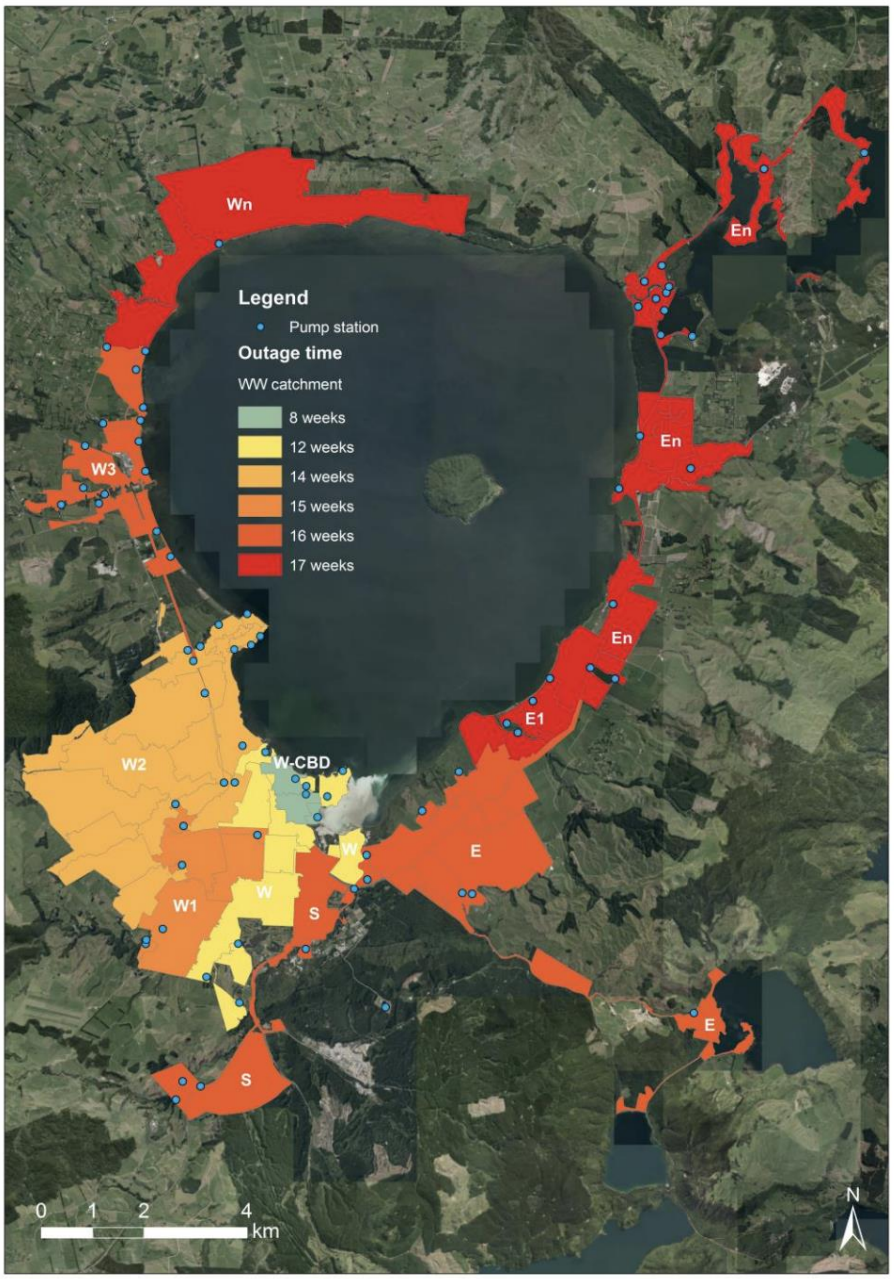

Figure 2: Interview example two (Simulated outage map for wastewater network, hazard scenario)

Visual prompts were introduced as they can be useful in grounded theory-based interviews to enhance data collection and analysis by stimulating participants' thinking, encouraging deeper

reflection, and facilitating the expression of complex ideas. It was anticipated that sharing these examples would elicit deeper insights from participants and serve to establish rapport (Glegg, 2019). The use of these prompts was designed to encourage participants to share their experiences as both users and producers of complex hazard and risk information and supporting communication, including visual outputs.

2.3.4 Reflections on interviews

Reflection on the style and delivery of questions and early analysis of findings was undertaken after conducting the first two interviews, to ensure that the approach was gathering data as intended. Questions were retained without revision; however, use of prompts was refined throughout the interviews, as participants tended to describe barriers to (as well as opportunities for) incorporating multi hazard and cascading hazard information into their work throughout the course of reflecting and describing their experiences, and in response to visual prompts.

2.3.5 Ethics approval

Once the research design was created, and before recruitment began, ethics was considered in accordance with Massey University's Human Ethics Committee guidelines. Analysis of any potential ethical issues and appropriate management processes were described. Ethical considerations included avoidance of harm, consent, confidentiality and anonymity, data protection and avoidance of conflict of interest. Additional documentation submitted for ethics approval included details of the research aims, methodology and data collection processes. Massey University's Risk Assessment screening checklist was used to determine that a low-risk notification was the appropriate ethics approval procedure for this project and details were submitted and approved on that basis (Ethics Notification Number: 4000026215).

Supporting participant materials were created in alignment with Massey University Ethics Committee guidelines, including a consent form and information sheet included as Appendix B and C respectively. These materials informed participants of the research project aims and objectives as well as clarifying how research data would be treated and stored to ensure participant confidentiality. The information sheet and consent form were provided to participants ahead of the interviews, and both documents were reiterated and discussed during the introduction to each interview to ensure participants fully understood and agreed to the proposed approach. Completed consent forms were collated via email ahead of interviews and consent to record was also verbally obtained at the beginning of each interview.

2.4 Interview data collection

Introductory email invitations were sent to potential interview participants that had been identified during the participant selection process. Introductory emails outlined the context and purpose of the intended research, as well as background information to understand why they had been identified as potential participants. This approach resulted in some further email exchanges to discuss the nature of the research, and in some instances referrals to other colleagues were made during this discussion. For those who decided to participate in the research project, interview date and time was confirmed and additional information was provided (including the information sheet and consent form), and further discussions were had regarding these materials in some instances.

As these interviews took place during a time of heightened awareness of COVID-19 pandemic impacts in New Zealand, all participants were interviewed virtually using Microsoft Teams software to reduce the risk of transmitting the virus. The virtual interview method also allowed for a greater geographical spread of participants to be interviewed than would have been otherwise possible. All participants were comfortable with this approach and familiar with this way of working in 2022, which created a more relaxed and conducive interview environment (Braun & Clarke, 2013). To conduct the interviews in alignment with grounded theory principles, effort was made during data collection to establish a conducive and interactive environment to encourage participants to openly share their experiences and perspectives.

2.4.1 Transcription

All nine interviews were recorded with the Microsoft Teams software, which has functionality to video record as well as generate a basic automated voice-to-text transcript. Active consent was sought from all participants to use these tools, and data storage and use was discussed in alignment with Massey University ethical guidelines. Participants were advised interviews would be approximately 1 hour in length. Most interviews were approximately 45 minutes long, one interview was shorter, and some took the full hour of allotted time.

Automated transcriptions were carefully reviewed after the interviews against original recordings to ensure accuracy and completeness of data. While the New Zealand accent negatively impacts the accuracy of transcription for the Microsoft Teams voice-to-text software, automated transcripts were a helpful initial aid to facilitate a basic level of data capture. Manually corrected and completed transcripts were then imported into qualitative data analysis software (NVivo) to enable detailed data coding and analysis.

2.5 Interview data analysis

Analysis is the process of making sense and giving meaning to data. Corbin & Strauss (2014) describe a process of deconstructing data, conceptualising it in terms of unique properties and examining individual pieces to understand ‘the whole’.

Interview data analysis for this project involved taking detailed memo notes during interviews, comparing these with interview transcriptions, coding and analysing the data, making further annotations to describe codes, using a method of constant comparison between the data and the codes, and then comparing and refining the codes themselves (Charmaz, 2014).

2.5.1 Data coding

Grounded theory interview data coding involves a multi-stage process including initial coding, focused coding, and theoretical coding (Corbin & Strauss, 2014).

Initial coding, also known as open coding, was the first step undertaken in the data coding process. It involves breaking down the data into meaningful segments and assigning descriptive codes to capture the meanings of each segment. For the first interview transcripts, line by line coding was employed as a means of initially penetrating the data and beginning to identify a comprehensive list of concepts, ideas and themes emerging from participants’ responses (Charmaz, 2014). There were 145 unique individual codes generated during initial coding.

Focused coding, also called selective coding, was then undertaken to revisit the data and identify core categories and concepts emerging from the initial coding. These included concepts associated with the terminology used for multi hazard and cascading hazards as well as more detailed groupings of reflections on the use of risk and hazard data, communication considerations and collections of barriers. The most relevant codes were selected, refined, and constantly compared with each other to identify relationships, similarities and differences (Charmaz, 2014). Interview memo notes were constantly referred to during this process as patterns and associations were explored.

Theoretical coding, which aims to further refine and articulate the relationship and connections between data to understand the meaning and explanatory factors within the categories, was then applied as the final stage of interview data analysis, which was only possible after a rigorous comparison of the initial and focused coding, a consideration of memo notes and code annotations, and revisiting of the research literature (Glaser & Strauss, 2017). This process was

iterated until saturation was reached, where new data no longer warranted adjustments to categories.

2.6 Results interpretation and development of recommendations

The theoretical coding process allowed for the articulated concepts of multi and cascading hazard terminology to be visually mapped, showing the relationship between concepts.

In addition to the visually mapped definitions, five main theoretical codes emerged in relation to:

- access to data
- sense-making and interpretation of data
- using information to support decision-making
- the importance of collaboration, and
- communication tools.

Development of new theory was not the primary aim of this research project; instead, the grounded theory approach was used to explore how data from the experiences of New Zealand practitioners aligned to existing theory within the literature. The identified themes above were assessed in the context of the initial literature scan, which helped to focus the literature review on multi and cascading hazard and risk definitions, core concepts, risk perception in multi and cascading hazard contexts, as well as narrative and visual storytelling in the context of risk communication.

The identified concepts and themes from the data were considered in relation to the established theory from the literature, as well as consideration of the specific risk reduction context in New Zealand outlined in Section 1.3. This allowed for the development of recommendations in the form of guiding principles to inform good practices for communication specific to the hazard and risk communication field in New Zealand.

2.7 Limitations to research methodology

Limitations to the research methodology include: factors associated with the availability of participants, as not all originally identified practitioners were available to participate during the data collection period; the spread of participants across functions, due to the range of professional areas identified in Section 2.3.1, which resulted in a smaller subset of participants from each area; and the virtual interview method itself. Remote data collection has traditionally been considered to be a less optimal approach for undertaking qualitative interviews (Rubin &

Rubin, 2012), although research is emerging which suggests that virtual interviewing and remote data collection techniques may provide benefits that have become more apparent in the post COVID-19 context, including access to a wider range of participants (Keen et al., 2022). However, limitations of the virtual interview approach are known to include challenges with recognising and responding to non-verbal cues (Reñosa et al., 2021). A greater mix of in-person and virtual data collection could therefore surface additional insights.

Additionally, this project used a grounded theory qualitative data collection approach designed for investigating detail and nuance. To test and generalise the research findings more broadly, a wider mixed methods approach utilising a survey with a range of participants would ideally be required to promote confidence in generalisation (Polit & Beck, 2010).

3. Literature review

3.1 Overview

This chapter contains a review of research findings drawn from several academic disciplines and is used to develop and refine the basis and conceptual framework for approaching the research questions outlined in Chapter One (Berg & Lune, 2017).

In the first instance, a broad spectrum of research is examined which looks at how humans understand and perceive risk, touching on psychological heuristics and biases. This literature was drawn from various research domains including hazard research, behavioural, health and risk science discourse. This is followed by a consideration of how hazards and risks are communicated in light of those understandings and perceptions.

Emerging literature-based professional discussions and use of terminology associated with multi and cascading hazards and risk are then also explored, including a consideration of the key concepts these terms are representing.

The final focus of the literature review is on risk communication strategies. As well as exploring general strategies related to risk communication, narratives are also specifically considered as a way of understanding how humans relate to and make sense of information. The application of narrative communication as a technique is reviewed, including ways of incorporating visual information into those narratives. The purpose of examining the literature on narratives was to determine if this communication approach could have potential as a risk communication tool for non-technical decision makers.

At the close of the chapter, key themes from the literature are identified, as well as any gaps or areas deserving of further inquiry.

3.2 Perceptions of risk and biases

3.2.1 General human perception of risks and biases

Social researchers have developed theories and frameworks to describe the various psychological or behavioural factors at play that influence how people respond and prepare in the face of hazard risk. These theories are based on observable heuristics and biases and generally incorporate different elements of interpretation (risk perception), emotional elements

(affective responses) as well as other relationship variables (e.g. community context, social capital etc.) (Paton, 2019).

The observation of various psychological biases can often be explained by the human tendency to employ mental shortcuts or 'heuristics' (Kahneman et al., 1982), a topic of central importance in the literature on psychological risk perception. Heuristics is a term from cognitive science and can be thought of as simple and efficient 'rules of thumb' that work well for the task at hand, most of the time, especially where quick judgements are required (Finucane et al., 2000). Studies of adaptive behaviour acknowledge that humans developed heuristics that allow for 'fast and frugal' decision making which has overall served the species remarkably well (Gigerenzer et al., 2011). However, risk literature has often interlinked the concepts of heuristics and cognitive bias with a negative framing as an illustration of the way that the innate logical fallacies of our brains can impact decision-making. Positive or negative interpretations aside, it is known that humans do not always make logical decisions based on available risk information.

Risk perception as a distinct field of social inquiry emerged from research in the 1970s and 1980s that focused on trends of human behaviour which were not objectively logical and the observable psychological biases in 'risky' decision making scenarios. This work shaped our understanding of how human factors can influence people's understanding of and response to hazard risks. For example, '**Prospect Theory**' was developed to describe how people evaluate and make decisions under risk and uncertainty, emphasising that individuals are more sensitive to potential losses than gains and often deviate from rational choice models (Kahneman & Tversky, 1979). This research showed that people generally prioritise the certainty of an outcome when the options were all positive (for example, a certain amount of financial win vs an uncertain but potentially higher amount), but they found the opposite was true for negative outcomes—people would take a gamble with a potentially higher loss versus the certainty of a lower loss.

Another bias related to risk perception, including natural hazard risk, is **optimistic bias**, wherein people often perceive themselves less likely to be impacted by the risk in comparison to their peers, especially for hazards rated low in probability or with which they have little personal experience (Weinstein, 1989). This has been observed in those who have survived previous earthquakes without loss; however, it is diminished if the prior experience included loss or injury (Solberg et al., 2010). Relatedly, **normalcy bias** the tendency of individuals to underestimate

the possibility of a disaster or crisis occurring and assume that things will unfold as they typically do. This bias can impede effective hazard and risk preparation and response efforts in disaster contexts, as individuals may delay or ignore necessary precautions due to an unwarranted belief in the continuation of normalcy (Omer & Alon, 1994).

Both context and overarching cultural norms which influence individual perceptions are important to risk perception bias, with some psychological phenomena being readily observable and others which are not as immediately obvious (Palm & Carroll, 2018). As humans we know on an innate level that our **past experiences** shape how we see the world. The research into psychological factors that increase risk perception has shown that past experiences of damaging events certainly increase concern; however, the 'strength of concern' is murkier and influenced by unique features of personal experience, such as levels of personal loss (Solberg et al., 2010).

The **availability and representative heuristics** are observations first described in the 1970s. The availability heuristic refers to a mental shortcut where judgments and decisions are based on the ease with which information comes to mind (Tversky & Kahneman, 1973). It has been documented that people tend to rely on readily available and easily recalled examples when estimating probabilities or likelihoods. This heuristic operates on the assumption that if a particular event is easily recalled, it must be more common or probable, even if this may not be objectively accurate. The **representativeness heuristic** is a similar cognitive bias where individuals, operating in conditions of uncertainty, judge the likelihood of an event based on how similar it is to a prototype or existing mental category. This bias can lead individuals to overestimate the probability of events that closely match their mental image of the way they think that event might unfold, potentially impacting risk perception and decision-making (Kahneman & Tversky, 1972).

Emotional elements, or 'affective response' as described in the literature, describe how positive and negative feelings are an essential component of judgement and decision-making. It has been noted that people use an **affect heuristic** to make judgements, with benefits being seen as outweighing risks for activities that are 'liked', and an opposite tendency observed for activities that are 'disliked' (Finucane et al., 2000). It has been proposed that in the context of risk and benefit decision-making, not only is the ability to imagine, or remember influencing judgement (availability and representative heuristics), but so too is a subconscious consultation

of all the positive and negative associations that people may have about a situation (Finucane et al., 2000).

Perceptions of control and people's belief in their own ability to influence outcomes (**self-efficacy**) has a significant impact on their ability to process fear-inducing, peril-related information, and the combination of a major threat and the belief that one's actions to mitigate the threat will not work have been observed to lead to fear, denial, avoidance of information, an unwillingness to think about the future, or even to anticipate the threat at all (Paton, 2019). The flip side of this is seen in research looking at risk perceptions of events with high severity but a long return interval (such as volcanic eruption), with '**response efficacy**', or how useful people perceive an action as being likely to reduce harm, being the biggest predictor of emergency preparedness actions (Peers et al., 2021).

The human tendency towards denial and fatalism can also have an outsized impact on perception of risk, and more importantly, people's perceived agency to be motivated to address that risk. **Fatalism** (the belief that there is no point in taking action since it will make no difference and will be a waste of time) can be influenced by whether the personality attribute of 'locus of control' is internal (I have control of the situation) or external (the situation is controlling me). Communication products that reinforce an internal locus of control have been shown to be more effective in spurring action (McClure, 2017). The related tendency of **denial** (that is, coping with an anxiety-producing event by denying the seriousness of the risk to reduce that anxiety) can obviously have a distorting effect on risk perception. Studies of people's level of earthquake preparedness, for example, have shown that those who had taken fewer precautionary measures underestimated the likely damage to a greater extent suggesting that those who make fewer precautions cope with the threat of a disaster by denying its likelihood (Paton & McClure, 2013).

3.2.2 Risk perception in a disaster risk reduction context

Given the sheer variety of inherent biases and heuristics that influence human decision-making at many levels, "an overwhelming number" of behavioural models have been proposed to inform behaviour change efforts, ranging from generally applicable models to ones specifically developed within the natural hazard field (Vinnell et al., 2023a, p. 3).

Models dealing with behaviour around health risk (e.g., Health Belief Model (Janz & Becker, 1984), Theory of Planned Behaviour (Ajzen, 1991), and the Risk Information Seeking and Processing Model (Griffin et al., 1999)) are seen as particularly applicable to the natural hazard field, given their focus on modifying specific behaviours to mitigate specific risks (Vinnell et al., 2023a). Health-related research has also proposed a 'dual-process model' theory where a response to a perceived threat occurs simultaneously within a cognitive system of rational deliberation focused on 'danger control' and taking actions to reach a safe state, and an affective system of automatic emotional response focused on 'fear control' and the fight or flight reactions to reach a state of relief (Daniel, 2007).

In the disaster risk reduction space, several models have been developed (Vinnell et al., 2023a), including the Person-relative-to-Event Model (Duval & Mulilis, 1999), Protection Motivation Theory (Tanner et al., 1989), the Extended Parallel Process Model (Witte, 1992), the Protective Action Decision Model (Lindell & Perry, 2012), and Community Engagement Theory (Paton, 2013). Research in this space has also examined the sometimes subtle human ways in which people perceive and act upon hazard risk, including assessing what people mean when they say something is (or is not) 'risky' (Slovic, 2000).

Of course, it is a challenge to be able to predict with any certainty how effective a risk reduction action could potentially be. Daniel (2007) writes that a delicate balance must be struck between fear of a negative future outcome and the costs/efforts and sacrifices that taking pre-emptive risk reduction action require—with the major spanner in the works being uncertainty. Doyle et al. (2019) note a wide range of ways in which uncertainty influences science advice in a natural hazards context, ranging from stochastic uncertainty inherent in natural systems, to epistemic uncertainty (lack of knowledge), to various levels of scientific uncertainty including everything from incomplete data to lack of established consensus. They further note that strategies to deal with these many shades of uncertainty need to move beyond communication processes and encompass wider contexts such as what information is required at what times and the psychosocial processes at play before, during, and after events. In their overview of the major behavioural models applicable to disaster risk reduction, Vinnell et al. (2023a) reach a similar conclusion, noting that the choice of model appropriate for a given situation depends on who the target audience is, what behaviour you want them to undertake, what channels do you have available to change that behaviour, and what and where are the pre-existing barriers to people undertaking the target behaviour.

In summary, the various psychological and perceptual biases noted above can have an outsized influence on the understanding of and relationship to risk, especially when dealing with hazards, risks, and vulnerabilities as large and complex as those related to natural disasters. These biases can influence understanding, interpretation and use of hazard and risk information in general, including in multi and cascading hazard and risk contexts. This suggests that risk communication practitioners need to be continuously aware of the influence of the state of mind of their many audiences, including professional practitioners themselves, as, essentially, the way that audience feels about the information they are receiving will potentially have as much impact on their ability to make sense of that information as that data contained within it.

3.3 Multi-hazard and cascading hazard

Given the wide variety of influences on perception and use of hazard and risk information, it is worth considering what this means specifically in the context of multi and cascading hazard and risk. In recent years there has been increased interest across a wide variety of disciplines of research in describing and studying disaster events that involve multiple overlapping or consecutive hazards and risks. It has been argued that the reason for the explosion of interest is due to an increase in costly, complicated disasters arising from events impacting an ever-more interconnected world, leading scholars and professionals studying these events to desire more precise language to define and discuss what they're seeing (Cutter, 2018).

Globally, researchers are observing how climate change, including extreme temperatures, is creating disastrous conditions, leading to extreme weather events, which in turn lay the foundations for even more extreme events (AghaKouchak et al., 2018). The interconnected nature of hazard conditions and risk is increasingly being described with terms such as compounding and cascading hazard (or risk). The terms multi or multiple hazard and cascading hazard are increasingly used in professional discourse in New Zealand and overseas, particularly for those who are directly working in spheres which include disaster risk reduction, readiness, response, and recovery.

Beyond awareness of natural hazards and their immediate physical impacts, researchers are observing the connections between (different kinds of) event shocks and disastrous effects with increasing interest, taking a broader view of hazard environments and the way in which disaster episodes are linked (Perry, 2018). As a result, evolving vocabulary is emerging within professional spheres and areas of research to describe those connections. Some of these

terms, such as ‘multiple hazard’ or ‘multi-hazard’, ‘cascading events’, and ‘cascading effects’, are used synonymously in scientific literature (Zuccaro et al., 2018).

3.3.1 Definitions

3.3.1.1 General terms

One of the obstacles to arriving at a clear, shared understanding of terms related to multiple and cascading hazards and risks is that the core component terms used for describing these concepts often themselves have fluid, evolving definitions. Terms such as ‘hazard’, ‘risk’, ‘impact’, and ‘vulnerability’ need to be understood before meaningfully discussing interactions of multiples of each.

The United Nations Office for Disaster Risk Reduction (UNDRR) has produced terminology guides since the early 2000s in accordance with their mandate to coordinate, campaign, advocate for, inform, and monitor disaster risk reduction policy, data, and research, and their definitions for these terms have become widely cited and relied upon within the field of disaster risk reduction (Staupe-Delgado, 2019). Other frequently cited definitions come from the Intergovernmental Panel on Climate Change (IPCC) and the Federal Emergency Management Agency (FEMA) in the USA. Definitions from these three sources are considered and compared below.

Hazard is defined by the UN as “a process, phenomenon or human activity that may cause loss of life, injury or other health impacts, property damage, social and economic disruption or environmental degradation.” Hazards may be natural, anthropogenic or socionatural (a combination of the previous two) in origin (UNDRR, 2017, p. 18).

The UN refers to **vulnerability** as “the conditions determined by physical, social, economic and environmental factors or processes which increase the susceptibility of an individual, a community, assets or systems to the impacts of hazards.” (UNDRR, 2017, p. 24) while the IPCC defines it as “the propensity or predisposition to be adversely affected”, adding that this includes a “sensitivity or susceptibility to harm and lack of capacity to cope and adapt.” (IPCC, 2022, p. 2927). Brooks (2003) draws a distinction between *biophysical vulnerability*, which is roughly equivalent to hazard risk, and *social vulnerability*, which is based on the internal characteristics of human systems and behaviours.

Disaster risk is defined as “the potential loss of life, injury, or destroyed or damaged assets which could occur to a system, society or a community in a specific period of time, determined

probabilistically as a function of hazard, exposure, vulnerability and capacity" (UNDRR, 2017, p. 14). Staupe-Delgado (2019), in analysing the difference between the UN's 2009 and 2017 guidance, notes that the later version refers almost exclusively to "disaster risk" where the earlier used simply "risk", and speculates that this may reflect an effort to draw a distinction between the broad use of risk in a technical and probabilistic sense and the more disaster-focused understanding of risk as related to vulnerabilities, impacts and coping capacity. Similarly, guidance published by the IPCC around risk communication notes that their organisation always considers risk to be negative in a disaster context, and that the probability of positive outcomes should be referred to using different terminology (e.g., "opportunity" or "potential benefit") (IPCC, 2020).

While the concept of **impacts** is not explicitly defined by the UNDRR, the IPCC defines it thus: "The consequences of realised risks on natural and human systems, where risks result from the interactions of climate-related hazards[…], exposure, and vulnerability… Impacts may be referred to as consequences or outcomes, and can be adverse or beneficial." (IPCC, 2022, p. 2912).

In essence, *hazard* is understood to be the source of potential harm, *vulnerability* focuses on the conditions that make a system susceptible to harm, while *risk* considers the probability of a hazard happening and the magnitude of potential damage, which ultimately manifests in the real world as *impact*.

3.3.1.2 Multiple hazard, or multi-hazard

The United Nations definition of '**multi-hazard**' is broad and specifically includes cascading events within the definition of a multi-hazard approach. The United Nation's Sendai Framework for Disaster Risk Reduction (United Nations, 2015) refers to multi-hazard approaches and has included this sub-term within the broader framework of understanding hazard through iterations of the UN definitions documents. Researchers looking at the evolution of this policy-level language from the UN between the 2009 and 2017 versions noted that the definition of **hazard** itself had been broadened by 2017 to specifically reference six sub-terms: **multi-hazard, biological hazard, environmental hazards, geological or geophysical hazards, hydrometeorological hazards**, and **technological hazards** (Staupe-Delgado, 2019).

The United Nations Office for Disaster Risk Reduction now includes the following definition for **multi-hazard**:

> *Multi-hazard means (1) the selection of multiple major hazards that the country faces, and (2) the specific contexts where hazardous events may occur simultaneously, cascadingly or cumulatively over time, and taking into account the potential interrelated effects. Hazards include (as mentioned in the Sendai Framework for Disaster Risk Reduction 2015-2030, and listed in alphabetical order) biological, environmental, geological, hydrometeorological and technological processes and phenomena. (UNDRR, 2017, p.19)*

It is worth noting that this UN definition considers the concept of '**cascading hazard'** (expanded upon below) to be a sub-type of multiple hazard. As such, this thesis will refer to 'multi and cascading hazard' throughout when referring to these linked concepts together.

The term 'multi' or multiple hazard is often used to describe an approach to risk reduction or readiness activity which considers a range of distinctly separate, but possible, hazards which could present a risk to human activity. This is sometimes also called an '**all hazards approach**' describing a multi-hazard landscape with many separate individual risks (seismic, weather, isolation-related) and the inherent susceptibility (infrastructure, social) to impact from those risks (Dunant et al., 2021).

3.3.1.3 Cascading hazard

As a phrase, '**cascading hazard**' is of a recent coinage, with a basic keyword search of Google Scholar showing the first instance of the phrase appearing around 2004, in contrast to the terms 'multi-hazard' or 'multiple hazard' which appeared in a disaster context in the late 1980s.

The idea of cascades or cascading hazards is more strongly associated with the interrelationship or link between events or impacts. The IPCC defines **cascading impacts** as an event where "an extreme hazard generates a sequence of secondary events in natural and human systems that result in physical, natural, social or economic disruption, whereby the resulting impact is significantly larger than the initial impact" (IPCC, 2022, p. 2902).

While 'cascading' is one of the most used terms to describe these interrelationships, it is just one of many terms or phrases that have been put forth to describe similar concepts, including interactions, chains, domino effects, compound hazards, or coupled events (CDEMA, 2014). What these concepts have in common is the core idea of a relationship between hazards, their risks, and their impacts.

It is worth further exploring cascades and related terms to understand why they exist, why they are increasingly popular, and what the core concepts represent. In 2015, Pescaroli & Alexander posited that **cascading effects** were associated more with the magnitude of vulnerability than

with that of the hazard. By 2019 they were arguing that the concept of 'cascades' is an entirely new paradigm of disaster studies (Alexander & Pescaroli, 2019). This new paradigm is described in terms of the high levels of dependency on infrastructure and networked systems which support modern society. Cascades in this context is used as vocabulary to talk about the levels of complexity associated with system failures.

> *Cascade, compound, complex hazards and disasters. Does it really matter what we call them if we intuitively understand what they are and their repercussions? Cascades occur as a consequence of the loss of capacity in one system overwhelming a connected system, elevating the impacts from hazard to disaster to catastrophe. The unanticipated consequences ripple through systems sometimes in an orderly and often predictable fashion, but mostly they generate surprise at the nature and magnitude of impact near and far. The lack of foresight, lack of thinking beyond the range and geographic extent of most obvious outcomes, disconnected patterns of governance, and failures in decision making all contribute to our collective moral failure to not expect the unexpected and prepare for surprise. The lack of political will, institutional brittleness, absence of creative thinking, myopia, and selfishness masquerading as protectionism all constrain our ability to moderate the adverse consequences of these types of events, suggesting that cascading disasters are now the new normal or, better yet, the new abnormal. (Cutter, 2018, p.25).*

The above excerpt illustrates a theme about the use of cascading hazard and related terminology in the literature, specifically that perhaps the choice of words is less important than the concept they are trying to convey, which is one of highly connected systems and their ability to fail in seemingly 'surprising' ways. This raises the question of how do we eliminate surprise and catastrophe caused by our highly connected systems? How do we set up our political and institutional systems to effectively incorporate 'foresight' and prepare for surprise?

3.3.1.4 Definitions in New Zealand context

In the New Zealand legislative context, none of the major pieces of legislation discussed in Section 1.3 explicitly define multi-hazard or cascading hazard, although they do offer some definitions of more general hazard concepts. The Resource Management Act defines "**natural hazard"** as "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, or other aspects of the environment" (Resource Management Act 1991, 1.2 Interpretation), and the Local Government Act references this definition directly, bringing at least these two into alignment (Local Government Act 2002). The Civil Defence and Emergency Management Act offers its own definition of "**hazard**" but not 'natural hazard' (as does its

proposed replacement, the Emergency Management Bill currently before the NZ Parliament Select Committee) (Civil Defence Emergency Management Act 2002; Emergency Management Bill 2023). The Building Act has its own narrow definition of '**natural hazard**' which includes hazards with most obvious relevance to structures: erosion, falling debris, subsidence, inundation, and slippage (Building Act 2004).

In the absence of clear and consistent legislative definitions, the primary guidance for New Zealand comes from professional guidance written by and for the sector. For example, in recently released professional guidance the New Zealand Ministry of Civil Defence & Emergency Management (2022) highlighted cascading hazards for consideration when undertaking hazard risk assessments. Specifically, **cascading hazard** is described as an ability for one hazard to trigger or exacerbate another hazard. It is worth noting that 'multi-hazard' is not explicitly called out or defined in this document; however, this guidance does refer to "cascading or concurrent hazards" and suggests an exploration of these more complex situations might be something to consider, but only after single hazard scenarios have been worked through.

The National Disaster Resilience Strategy (2019), while not explicitly defining multi and cascading hazard, leans heavily on the interrelated nature of both the nature of the hazards facing New Zealand and the systems put in place for preparing for and responding to those hazards, making frequent references to the need to understand and account for that complexity. The Natural Hazards Risk Communication Toolbox, developed by Auckland Council (2014) in conjunction with GNS Science, is more explicit, dedicating a section to defining the difference between "**cumulative hazards"** and "**cascading hazard**", noting that the distinction between the two is that the former are unrelated to each other, and the latter occur because of the same triggering event. These same definitions are seen in other New Zealand guidance, such as the Bay of Plenty Regional Council (n.d.) Natural Hazard Risk Assessment User Guide, which describes cumulative hazards as an area's exposure to more than one type of natural hazard risk (e.g. flooding and fault rupture), with cascading hazards being two or more natural hazards caused by the same trigger event.

The implications of the lack of agreed-upon standard definitions for multi and cascading hazard within the New Zealand disaster risk reduction sector are explored in Chapters Four and Five of this thesis.

3.3.2 Concepts

3.3.2.1 Simultaneous, cumulative, compounding hazards

While the definition of multi hazard at its broadest can simply indicate that more than one hazard has the potential to impact an area, it is possible that more than one of these hazards can result in events occurring at the same time, without the causal link between them that would make them ‘cascading’. There clearly are nuances in the literature in relation to how some of these concepts are described.

As an example, in August 2023, as Hurricane Hilary was making landfall in southern California, the region was struck with a magnitude-5.1 earthquake while a 2,000-acre wildfire was forcing evacuations (Fuller, 2023). While these three events represented the realisation of multiple hazards, this was considered a ‘simultaneous’ rather that ‘cascading’, as there was no causal link between them other than bad luck.

While this situation in California fits the definition of cumulative hazards as described in New Zealand guidance such as the Auckland Council Natural Hazards Risk Communication Toolbox (2014), the language of cumulative *risk* is also well established in the health sciences, where it represents a slightly different concept, namely being the combination of risks posed by aggregate exposure to something potentially harmful, such as a chemical compound (National Research Council, 2009). Aggregate exposure, in the context of hazard and disaster literature, appears to be more closely associated with the term ‘compound risk’, which is described as something which may “arise from the interaction of hazards, which may be characterised by single extreme events or multiple coincident or sequential events that interact with exposed systems or sectors” (IPCC, 2022, p. 2921). An example of this might be an earthquake prone brick building that sits for many years upon reclaimed land which is known to be susceptible to liquefaction, in an area overdue for a significant seismic event.

3.3.2.2 Elements of cascades

The connotation of ‘cascade’ evokes a movement or path of travel for something, such as a waterfall, or a linked sequence of events, like dominos falling. The Cambridge University Press (n.d.) online dictionary describes the verb form of cascade as something falling quickly and in large amounts, or a flow.

As previously defined, cascades in the context of hazards are commonly seen as being causal chains that have subsequent effects. However, the ‘links’ in those chains may include any of the following:

- **Hazard to hazard**, such as an earthquake causing a tsunami.
- **Hazard to risk(s),** such as intense rainfall increasing the risk of flash flooding.
- **Hazard to risk(s) and effect(s) or impact(s),** such as this example from FEMA’s definition of a cascading event: a flood disrupting electricity supply, which causes a traffic accident, which causes a hazardous material spill which causes the need to evacuate an area and a stream contamination (FEMA, 2021).

In addition to the direction of the causal links, there are important considerations that influence the magnitude of those effects, most notably time and human behaviour. An example of the effect of time on a cascading hazard is an oil spill that grows worse hour by hour until the flow is cut off. And human behaviour can have any number of exacerbating effects, from familiarity with risks to compliance with evacuation orders. Zuccaro et al. (2018) note that these variables of time and human behaviour must be included to fully apply their proposed model for analysing cascading effects.

3.3.2.3 Distinction between effects and impacts

Cutter (2018) describes compounding or cascading hazards in terms of linear pathways of casual events but makes a distinction with the term ‘cascading disasters’ as referring to and relying on complex interrelated sociotechnical systems or critical infrastructure (with social function dependency). That is, a disruption to one part of a system that then significantly worsens the scale of disaster impact. The Fukushima Dai'ichi power plant nuclear meltdown in the wake of the 2011 Tōhoku earthquake and tsunami in Japan is a well-known recent example of natural hazard impacts creating a cascading disaster where compromised infrastructure then massively impacted social systems (Eisler, 2012). Other examples include the stranding of 8.5 million airline passengers in 2010 due to ash from the eruption of the Icelandic volcano Eyjafjallajökull, despite light physical damage locally (Woolley-Meza et al., 2013).

Pescaroli & Alexander (2015) undertook a comprehensive international literature review to attempt to provide evidence-based definitions for the terms ‘cascading effects’ and ‘cascading disasters’, noting that it had become common place for scholars and practitioners alike to vaguely articulate these concepts and the metaphor of ‘toppling dominoes’ to describe complex related effects in disaster contexts. They argue that the occurrence of a linear casual chain of

cascading effects is actually very common in most disaster situations, with a triggering disaster event producing cascading effects amplifying disaster impacts. They argue these cascading impacts are complex and constantly evolving and that their key feature is close association with *vulnerabilities* (rather than the initial triggering event itself). Cascades can spread in space and time, but it is the inherent *system vulnerabilities* that are the defining feature (Alexander & Pescaroli, 2019). They argue that the concept of a 'cascading disaster' ought to be separate and distinct from concepts of 'cascading risk and effects', specifically when the amplified effects become so complex that the secondary effects are at least as serious as the initial main impacts. These unexpected effects make a disaster significantly worse.

The 2011 Tõhoku earthquake in Japan, and resulting consequences, certainly helped thrust the idea of a cascading disaster into the public and scholarly consciousness (Pescaroli & Alexander, 2015), as has more recently the COVID-19 pandemic. However, the latter is generally more widely referred to as a global crisis or series of disruptions (Clark-Ginsberg et al., 2021). So, while the term cascade is used to describe relationships between events and impacts, there are other terms used as well, such as the term 'concatenated crisis' used by Biggs et al. (2011) to observe and describe global shocks that increasingly interact with each other due to globalisation and climate change, like the economic relationship between food prices and energy/transport costs.

3.3.2.4 Systems thinking, system failure and critical infrastructure

Beyond the reference to causal chain reactions, and events and impacts that relate to each other, there is a broader idea discussed in the literature which closely aligns to the concepts of systems thinking. Specifically, the idea of system disruption, which has reached a heightened level of importance due to our globally connected human systems and very high level of dependence on critical infrastructure (electricity and communications networks, 'just in time' supply chains, etc.). Alexander & Pescaroli (2019) have argued that scenario mapping of critical dependencies to guide resilience activity is an area which requires far greater attention.

The system vulnerability concept is a clear theme that continues to surface as being of high importance. (Pescaroli et al., 2018) argue that another frame of thinking about cascading events is the 'accumulation of vulnerability paths', or more simply, problems waiting to happen. This flips around discussion which is otherwise focused on cascading events as being outcomes of occasional, but highly disruptive shocks. They argue that focus should be turned to vulnerability paths rather than solely the triggering event(s) themselves. The total vulnerability of the system

can be viewed as a function of the interaction between human behaviour and natural hazard risk (Brooks, 2003; Adger, 2006).

Research has been undertaken with critical infrastructure stakeholders and emergency managers in London which showed that cascading events and interdependencies (to the level of threat to life) were known concerns, however inadequately addressed within professional practice. A significant gap is evident between strategy and policy discourse and operational practice in terms of an approach to cascading risk (Pescaroli, 2018). It is recognised that decision-makers are now faced with the difficult prospect of trying to mitigate against not just single hazards and risks, but chains of events and their systemic interactions. However, methodologies for approaching this challenge are limited (Zuccaro et al., 2018).

3.3.3 Risk perception in multi and cascading hazard contexts

While the literature regarding risk perception both generally and in a single-hazard context is quite robust, studies of risk perception in a specifically multi-hazard context are less common and tend to find that the complexity of considerations for risk communication in this context increases significantly. Some examples that follow highlight the complexities of risk perception in such contexts.

A study of households in an area of Texas threatened by flood, hurricane, and toxic chemical release found that the external factors that most affected risk perception in a multi-hazard context were previous hazard experience (i.e., representativeness heuristic), gender, and income, with other factors having a lesser effect, but also noted that the influence of these factors varied depending on the hazard being discussed (Lindell & Hwang, 2008). The authors strongly recommend that hazard managers carefully identify their audiences, endeavour to understand their particular perception of the hazard(s) at hand, and craft their messages accordingly to suit. Another study based in Africa came to the similar conclusion that risk perception drivers vary by hazard and are shaped by both the characteristics of the hazard and the characteristics of the perceiver, noting that a better understanding of how people balance and prioritise protective action is essential, especially considering that those recommended protective actions can be as varied as the sources of risk (Sullivan-Wiley & Short Gianotti, 2017). Similar findings have come from a multi hazard risk perception study in Pakistan, which also found risk perception varying by hazard and notably influenced by gender of the perceiver (Khan et al., 2020).

Beyond just cumulative effects, it is also possible that in a multi-hazard situation concerns or fears about risks of one hazard can interfere with the expected mitigation of another. For example, concerns about health risks during the COVID-19 pandemic have been found to have modified behaviours during evacuation from natural disasters, leading to increased reluctance to evacuate on the part of elderly, and reduced likelihood of long-term sheltering. (Sohn & Kotval-Karamchandani, 2023). A related finding was observed in a recent New Zealand based survey of perceptions, attitudes, and behaviours in a multi-hazard environment, specifically asking people to think about earthquake and tsunami. Findings indicate that asking people about one hazard has a significant and meaningful impact on their judgement of a second hazard, often a decrease in risk perception (Vinnell et al., 2023b).

A notable gap in the existing literature is the limited understanding of how individuals specifically perceive and interpret cascading hazard risk, given that these types of hazards have been shown to have the potential to cause cascading or compounding impacts that may exceed the sum of each hazard occurring separately (Gill & Malamud, 2016). With the literature showing that previous hazard experience is a primary factor in risk perception and cascading hazard events are occurring with increasing frequency, there is ever more potential for a mismatch between lived experience and actual risk.

3.4 Risk communication strategies in disaster contexts

Considering people's perceptions, what does the literature advocate to be essential to effective communication, in ways that motivate risk reduction actions? Research has been undertaken to determine psychologically effective techniques for public risk communication approaches, acknowledging that the future is unknown and uncertain, and a certain amount of consensus has arisen around a few recommendations.

An emphasis on the usefulness of certain actions that can be taken now, with a particular focus on how they will lead to better outcomes, is a frequent theme. Researchers advocate concentration on positive action, not just awareness of risks and vulnerabilities. Doyle & Becker (2022, p.23) note that "communication should not solely focus on the risks and consequences […], but work to emphasise key actions to take and the efficacy of those actions", further noting that, as a principle, evaluation of this efficacy must be a part of this activity.

Another tactic recommended is frequency of communication (to raise 'hazard intrusiveness') and elicit emotional responses or connection (affective response). Studies have also found a positive correlation between the extent to which one thinks, talks, and reads about hazards and

their perception of that risk (Solberg et al., 2010), and the importance of talking about certainty and severity of hazard impacts to increase perceptions of personal consequences and motivate action (Peers et al., 2021).

Fear, as a communications frame, is generally unhelpful. It has been observed that in the context of risk communication, which often deals in visions of potentially disastrous futures, that exposing people to ‘fear-inducing content’ can help slightly in the short term with preparedness activity but is generally counter-productive over the long term and leads to fatalism and denial, and avoidance activity (Paton, 2019). As noted in the dual-process model theory above, the fear and denial of information can be seen as a psychological defence mechanism, although it is not mitigating the threat. This theory supports the approach that effective risk communication must strike the right balance between concern versus fear.

Doyle et al. (2019, p. 470), in an extensive review of literature around uncertainty in risk communication, conclude that the key to finding that delicate balance is to first understand the needs of the decision-maker receiving the information, and then to “concentrate efforts on evaluating and communicating the uncertainties relevant to those specific decision needs and time frames, rather than communicate all uncertainties which can overwhelm a communication and decision making process”. This understanding, combined with the increasingly networked nature of communications and the diversity of audiences served, has led to an evolution in best practices towards more social, collaborative, and tailored approaches. Meeting the needs of decision-makers, users, or audiences’ needs is consistently identified as a fundamental principle. However, note Doyle & Becker (2022, p. 35), “often resources are not available to meet this need; the timeframes available to co-create suitable communication ahead of required need may be too short. Or the various agencies and members of the public may have too many competing demands, or have other more pressing needs, that restrict their ability (or their desire) to co-create communication or plans for communication.” This, naturally, puts the onus on risk information producers to do more to understand where and to whom that information is going, and the context in which it will be received.

Early and ongoing collaboration with those audiences, then, becomes equally fundamental. Crawford et al. (2018b), in examining ways to improve end-user perceptions of risk modelling and its use in hazard risk management, recommend structuring for greater collaboration across multiple types of roles, involving those participants in the co-development of risk models through a bottom-up, participatory approach, the conducting of regular risk management workshops,

and a focus on enabling greater capacity and capability for (and openness of) natural hazard risk data collection, management and use.

It is also critical for practitioners to extend this two-way collaborative approach to their relationships with policymakers, keep pace with the rapidly changing policy environment, understand policy relevance and the distribution of decision-making control within the policy process (Balog-Way et al., 2020, from Doyle & Becker 2022). Among several other principles for effective risk communication, Doyle & Becker (2022, p. 32) propose:

> Recognising that a risk communication's scope may be constrained by legal requirements, institutional policies, and audience characteristics, each of which should be adequately identified at the outset in a 'planning phase' that considers legal requirements or organisational policies, the purpose of the communication, selecting the appropriate strategy for that purpose, identifying the characteristics of the audience (including receptivity and concerns, beyond knowledge and beliefs), and the sources of the audience.

These approaches can help to answer the fundamental question, from the perspective of decision-makers and other consumers of risk information, of 'So what?' Moving beyond a straightforward presentation of technical risk assessment content and using more social and collaborative approaches can help to move the dialogue towards the inclusion of issues such as vulnerability, "exposure, consequences, controllability, other people's experience with the risk, responsibility for negative consequences, and potential advantages" (Doyle & Becker, 2022, p. 13). Furthermore, it has been posited that adopting "a 'two-way' empowering worldview that considers and listens to audience needs as a central philosophy may help guide effective communication even when only a 'one-way' dissemination is actually possible" (Doyle & Becker, 2022, p. 35), implying that a possible path towards better risk communications lies closer to a commitment to a collaborative, multi-disciplinary approach rather than any particular focus on the information products themselves.

3.5 Narratives as effective communication tools

Alongside the importance of two-way communication, narratives are a useful tool for approaching hazard and risk communication. The application of narrative is especially useful in a disaster risk communication context because it addresses the negative impacts of the different types of biases (as outlined in Section 3.2 above). In particular, people's tendencies to rely on readily available and easily recalled examples when estimating probabilities or likelihoods of

risk, and to give added weight to those with which they are already familiar, suggests that the provision of clear and relatable scenarios or narratives can be valuable both in ‘peacetime’ in advance of a disaster, as well as when trying to interpret information during the response and recovery phases.

Narratives may also help with addressing the challenges inherent in the communication of multi and cascading hazard and risk information (as noted in Section 3.4), particularly the importance of focusing on the need to support decision-makers (especially those from a non-technical background) with the context around the meaning of technical data and the ultimate real-world risks, vulnerabilities, and impacts that data represents.

3.5.1 What is a narrative?

A narrative can be broadly thought of as a story, or “an account with a plot” (Corvellec, 2011, p.102), and therefore narrative communication could be described as storytelling, which occurs throughout human culture. Theoretical study has defined three distinct roles of narrative in our lives: as a basic form of social life, as a way of knowing, and as a mode of communication (Czarniawska-Joerges, 2004).

“As social beings, we live storied lives”, notes Bochner (2014, p.293). “Storytelling is both a method of knowing—a social practice—and a way of telling about our lives.” A narrative can be understood as a description of how events, often complex chains of them, are connected within a plot which serves to make connections between events, ultimately providing sense and meaning (Corvellec, 2011). Characters are the other key component, and how they deal with and react to events within the plot, setting, situation, and context moves the narrative forward. This provides the audience with context to make sense of the narrative by relating to the motivations and actions of the characters (Corvellec, 2011). It has been suggested that the ideal narrative is one that begins with a stable situation that is disrupted (by something) and then an action is required and taken that re-establishes a new and different equilibrium (Czarniawska-Joerges, 2004).

Researchers have looked at the broader functional role of storytelling in cultural contexts as a way of understanding life and how people construct meaning from the world around them (‘sense-making’). It has been noted that most of society’s learning can be viewed as storytelling—that is, we view people’s actions and behaviour in social life and derive meanings for that behaviour. Social researchers have gone as far to assert that a behavioural science view of bias and cognition can become ‘meaningless and mechanical’ on its own, as human

intentions can only be understood by appreciating the setting in which those intentions make sense (Czarniawska-Joerges, 2004).

Another distinct role of narrative is as a mode of communication in and of itself. People tell stories for a range of purposes: entertainment; teaching and learning; providing explanations; exploring ideas. Fisher (1987) asserted that fundamentally all human communication could be seen as stories and defined a 'narrative paradigm' structured around the concept of rationality, probability, and fidelity. Narrative rationality proposes that we should not try to define human rationality by following rules of logic, but instead need to follow narrative probability (a story's coherence and integrity) and narrative fidelity (a story's credibility, which is established by the presence of 'good reasons') (Fisher, 1987).

Fisher's 'good reasons' assume that humans *value* as much as they reason. While a traditional view of rationality presumes that the world is composed of logical puzzles and that humans employ reasoned analysis to decode these puzzles, Fisher asserts that it is the concept of the argument (as a product and a process) for decoding the world that is human and introduces a narrative metaphor to explain this, with accounting and recounting of the plot of human experience, others as subplots, the character of narrator(s), conflicts, and resolutions. In this way 'truth' is derived (Fisher, 1987).

Ultimately, these are the core assumptions within Fisher's narrative paradigm:

- Humans are natural storytellers and make sense of the world by viewing it as a set of stories (which are told and re-told and re-created).
- Human decision making and communication rests on 'good reasons', which vary due to situation and mode of communication, and are determined by history, culture, circumstance, and personal experience.
- Human rationality is not based on logic, but on how people behave as 'narrative beings', including their awareness of narrative probability and narrative fidelity.

A final concept is the practice of narrative inquiry as a method of qualitative research. Narrative methodology is a qualitative social science research technique in its own right (Czarniawska-Joerges, 2004). Narrative inquiry as a method of qualitative research, also known as 'the interpretive turn', has become increasingly popular since the 1970s and 1980s across a range of disciplines (Lyons, 2007). Narrative inquiry is positioned as more about conditions and the

meanings of experience as distinct from a logical scientific paradigm searching for ‘universal truths’ (Lyons, 2007).

3.5.2 The use of narratives in risk communication

If we lean in to the idea that stories are ubiquitous and that humans are hardwired to create, retell, and appreciate stories to make sense of the world, then the next questions are – what does this mean for risk communication? And can an understanding of how narrative communication works hold the potential to improve risk communication?

Research has been undertaken applying a narrative theory lens to risk communication, notably risk warning signs. This research drew a parallel to our earliest understandings of narrative storytelling from Aristotle – namely, a story has a plot, and there is a beginning, a middle and an end (Corvellec, 2011).

There are abundant instances of the use of narratives in risk communication, and research that has examined the effectiveness of these narrative interventions has found a positive impact on outcomes ranging from better compliance with official instruction to improved recall of information to more positive affective responses. Kreuter et al. (2007), in their work in the public health risk space, assert that narrative has four distinctive capabilities that are relevant to risk communication: overcoming resistance, facilitating information processing, providing surrogate social connections, and addressing emotional and existential issues. Specific examples of narrative-based risk communication include:

- A quasi-longitudinal study of communications to a community in Texas at risk of chemical exposure from a nearby manufacturing facility examined the strategic role of a narrative specific spokes-character (a turtle named Wally) in the delivery of those communications, finding that “knowledge of Wally and its protective response (including shelter-in-place) messaging is a strong predictor of community members’ preferred protective action and willingness to engage in such action once alerted to do so.” (Heath, 2019, p.1)

- In healthcare, a study of the prescription of potentially addictive opioid medication contrasted the presentation of the associated risks in a narrative format with the same information in a dry, written form. The study found that those presented with the narrative had lower preference for opioids, better recall of the risks at a later date, higher

satisfaction, and a better sense of shared participation in their own decision-making (Altshuler, 2022).

- A Dutch study of communications around the cancer risk associated with tanning bed use found that those participants who received this information in narrative form (specifically, a personal testimonial) reported higher feelings of risk than those who received the same information in other more purely factual formats (Janssen et al., 2012).

The framing of the attitudes of characters within narratives and the way in which those consuming the narratives identify with those characters can have a strong impact on the way that the risk information is received as well. A study of affective responses to a number of variations of flood warning messages presented to groups of representative community members in a flood-prone area of Montana found that narrative-based messaging presented through a 'hero' character elicited positive affective responses while similar messaging presented through a 'victim' character was received with a slightly negative affective response (Shanahan et al., 2019).

Dykes (2020, p.65) presents research showing that stories engage with different parts of the brain than do facts and statistics—"We hear statistics, but we feel stories"—adding that storytelling, importantly, "not only presents information in a way that is congruous with the narrative-seeking brain, but it can also ignite a desire in your audience to act". Narratives engage mental processes beyond language processing, including smell, touch, and movement. Over 30 years since Fisher wrote about the value-laden 'narrative rationality', Dykes reminds us that assuming that humans will make their data-informed decisions using only logic and reason is a common pitfall.

Dykes (2020) also introduces another common communication misconception called 'the information deficit model'. This is the assumption that an audience doesn't have enough information to fully understand and respond to a problem, and that this situation is solved by simply providing more information. Research has shown that people will naturally 'plug' gaps in their information to create a story which makes sense. The implication of this work is that for data communication, instead of simply providing additional data points, further work is required to create a new plausible 'story' for the audience to reconcile the new data. So, people will naturally fill in gaps with scenarios to make a good story, even if it's a best guess. This is how deep the human need for causality is.

3.6 Visual storytelling in risk communication

Within narrative communication, what role does visual communication play? We're all familiar with the phrase 'a picture tells a thousand words' and the area of practice of data visualisation, sometimes called 'data storytelling' is a growing field of interest that is attempting to bridge the gap between big and complex data sets and sense-making. Dykes (2020, p.26) who has written professional guidance on this topic, states that "the ability to effectively communicate with data is no longer a luxury in today's economy; it is a necessity. Transforming data into visual communication is only one part of the picture. It is equally important to engage your audience with a narrative--to tell a story with the numbers." This developing field recognises that the way a story is presented, aided by visual tools, will influence the decisions people make based on that data (Padilla et al., 2018).

Humans process information via two pathways: the verbal and the visual. Dual-coding theory suggests that communications which use both verbal and visual modalities have numerous positive effects, from enhancing comprehension, to improving memory and retention, to facilitating recall and recognition (Paivio, 1991). Accordingly, Dykes (2020) recommends blending data, narrative, and visual elements to create a cohesive story that effectively communicates the significance of what the data might be showing.

Visual storytelling not only facilitates better comprehension but also elicits stronger emotional responses, making hazard and risk information more engaging and memorable (Padilla et al., 2018). Effective visuals can clarify complex concepts, illustrate potential consequences, and highlight preparedness measures (Tufte et al., 1998) thus empowering stakeholders and the public to make informed decisions. Moreover, combining narratives with visuals fosters a sense of relatability, enabling people to connect with disaster scenarios on a personal level, which can drive proactive responses (Franconeri et al., 2021).

The topic of how best to design visual communications products for accurate perception is a vast and complex one, and a full study of best practices is well beyond the scope of this review. Briefly, however, much of what makes effective communications about disaster risk is broadly similar to guidelines for developing visual communications generally. Lipkus & Hollands (1999) confirm this view in the course of offering a number of guidelines for the visual display of risk information, including the display characteristics (e.g., use of colours, width of lines, or type and spacing of legends), conditions of presentation (e.g., lighting or time pressure), data complexity (e.g., number of data points or configuration of the display), etc. However, they further note that

“no single graphical format will perform optimally in all situations” (p. 157), and their proposed criteria for evaluating the effectiveness of a given visualisation are solely related to the audience’s perception of that product in context.

This necessity of understanding the needs of the audience is of paramount importance to hazard and risk communication, and repeatedly comes up as a core principle in the studies of the topic. One proposed framework for the user-centred development of visual communications tools around disaster risk breaks up the process into three phases (“Define, Design, and Refine”) which are then iterated, and it is notable that two of the three phases are about understanding the needs of the user and testing to ensure that those needs are being met, while only the middle phase concerns the actual creation of design products (Twomlow et al., 2022). Another overview of disaster managers’ views on what makes for effective visual risk communication emphasises understanding one’s audience, the channel of communication, the core message, and the intended goal, while hardly mentioning the quality of visual materials (Charrière at al., 2012). Communication products that are heavy on numerical data may be of interest and use to technical experts but may need to be presented in a format (such as ranges of probabilities, or colour-coded maps) that is more accessible for potentially non-technical decision-makers (Doyle & Becker, 2022).

Maps and other visually presented geographic information have been shown through research conducted in New Zealand and elsewhere to be particularly effective at helping audiences understand their relationship and susceptibility to hazards. Including by narrowing the gap between perception and reality for hazard management in a specific place (Khan et al., 2012), to increase awareness and resilience at the community level in risk prone areas (Auliagisni et al., 2022), and as powerful tools at the policy level for communicating with councils and the community (Crawford et al., 2018b).

3.7 Gaps and challenges in hazard and risk communication

This overview of the literature has uncovered several areas where coverage was scant or inconsistent, indicating a potential need for further exploration. Most notably, as shown above, terms at the heart of this research paper, **‘multi-hazard’ and ‘cascading hazard’ were found to have overlapping definitions depending on the source.** ‘Cascading’, in particular, was found to be used to describe a number of concepts. In the New Zealand context, no authoritative definitions were found to be clear and consistent across the relevant legislation,

and therefore the guidance produced by the sector for applying these terms and concepts is light.

Relatedly, literature regarding **the concepts of multi and cascading *risk* and *impact* is less robust than that of multi and cascading *hazard***, making it difficult to draw a distinction between the terms. For example, communications guidance from IPCC (2020) around how to present the concept of risk makes only a single parenthetical mention of “cascading or compounding risk” while enumerating and detailing a variety of other sub-definitions of risk. In practice, the general concept of “cascades” (and its synonyms) was found to cover discussions of hazard, risk (including vulnerabilities), and disaster in an overlapping manner.

While the literature on risk perception and risk communication strategies (including narratives) is robust, **gaps remain in specifically understanding multi and cascading hazard and risk perceptions and communication approaches** and **understanding the role of narratives in supporting practitioner dialogue about multi and cascading hazards and risks**. These gaps, coupled with inadequate definitions, could present communication challenges when trying to convey the vulnerabilities and consequences associated with multi-risk and cascading risk scenarios, potentially leading to reduced public awareness and engagement, research and regulatory gaps, and complicated and reactive decision-making by emergency managers. Ultimately, this has the potential to leave communities more vulnerable to complex, interconnected disaster scenarios.

This thesis will seek to explore these gaps and definitional inconsistencies from a practitioner/professional perspective. Aspects of perception and communication in a multi and cascading hazard and risk context are touched on in the Results and Discussion chapters below.

Additionally, a few areas that are considered out of scope for this paper but worthy of further inquiry include: a fuller examination of the effect of social and cultural factors on risk perception, particularly considering international and cross-cultural perspectives; the specific effects that changes in technology are having on best practices in risk communications; ethical considerations; and the outsized role that community engagement, public trust, and perceived trustworthiness play in the reception and retention of risk communications, particularly those originating from the government or other official bodies.

3.8 Summary

From this review of literature on psychological risk perceptions, concepts and definitions of multi and cascading hazards and risks, and communication strategies (including narrative communication) a number of key themes emerge:

Human behaviour and risk perception: Human decision-making is often influenced by cognitive quirks, and heuristics and biases can lead to unconventional decisions when assessing risks. Personal experiences shape how individuals perceive and evaluate risks, leaving a lasting impact on judgement in a way that often influences one's response to hazards. Emotions, such as fear, denial, optimism, or complacency, can sway our decisions and actions in the face of uncertain and potentially hazardous situations.

Impact on hazard and risk information: The interplay of human behaviour and risk perception significantly affects how hazard and risk information is interpreted and used, especially in the context of multi and cascading hazard and risk scenarios. The terms 'multi-hazard' and 'cascading hazard' may have nuanced interpretations depending on the context. In many cases, cascading effects are understood to be less about the physical aspects of the hazard and more focused on impacts and systemic vulnerabilities.

Complex networks and system failures: The reason terms such as 'cascading hazard' have gained prominence is likely due to the ever-evolving complexity of networks and the potential for cascading failures. As our society becomes more interconnected, failures in one area can have ripple effects, leading to unforeseen consequences and exposing vulnerabilities. Understanding more about cascading effects and their implications is vital for effective disaster risk reduction.

The power of storytelling: Human beings inherently make sense of their world through storytelling. In the context of disaster risk reduction, effective narrative communication becomes a powerful tool. Storytelling is not just a means of conveying information; it is a fundamental way that people process events and information, including filling in or plugging knowledge gaps with stories when there are unknown or uncertain factors. When risk communicators effectively employ narrative techniques, they can shape public perceptions, influence judgments, and guide decision-making.

Importance of presentation and visuals: The effectiveness of narrative risk communication can be enhanced by the presentation of the story and the use of compelling visuals. Visual tools

such as infographics, diagrams, and maps can enhance comprehension, memory retention, and public engagement when presented alongside narrative and/or data content.

Appreciation of context: Context is paramount in both understanding and crafting narratives. Effective risk communication requires not only conveying information but also connecting with people on a human level. Different audiences may require tailored narratives that resonate with their unique context and experiences. Recognising the importance of context, and specifically understanding what questions need to be answered by using the information, allows for more effective communication.

The literature detailed through this chapter will be discussed further in Chapters Four, Five, and Six in terms of research participants' understanding and use of multi and cascading hazard and risk information, and recommendations for how information can be developed and improved for effective communication and decision-making. Chapter Four begins by outlining the results of the interviews with risk reduction professionals.

4. Results from interviews

4.1 Introduction

This chapter examines the perceptions of multi and cascading hazard and risk information as reported by participants working in the New Zealand risk reduction sector, as well as the challenges and opportunities of applying this information to decision-making. It presents the results and observations from the data gathered through research interviews.

While a great deal of data was collected during the interview process, five key themes were identified as being of greatest relevance to the research focus of multi and cascading hazard and risk. Those key themes are:

1. Access to data
2. ‘Sense-making’ and interpretation of data
3. Supporting decision-making in the context of governance policies
4. The importance of collaboration
5. Communication tools

Data will first be presented on participants’ personal definitions and interpretations of multi and cascading hazards as well as their professional role and how it relates to risk reduction (Sections 4.2, 4.3). The key themes identified above are then discussed (Section 4.4). While these themes are discussed separately it is important to note that they overlap and intersect. Finally, several opportunities that participants identified to support better decision-making are presented (Section 4.5).

The key themes and opportunities presented synthesise areas where participants were generally aligned in terms of their perspectives. There was a greater divergence of perspectives when discussing terminology, definitions and interpretations of core concepts.

4.2 Definitions and interpretations of core concepts

Interview participants were asked to articulate their understandings of the terms ‘multi-hazard’ and ‘cascading hazard’ respectively, which then led to further discussion about how these concepts were understood and applied to professional practice and decision-making processes.

From this exercise it became clear that participants did not share a uniform understanding of these terms, nor were they explicitly and consistently defined within New Zealand professional

guidance or the different pieces of relevant legislation. In fact, inconsistent terminology was noted between legislation and definitions were understood to be specific to different contexts. However, participants were able to talk about their general understandings of these terms based on their experiences and how they applied these concepts to their work.

Interviewee H:

> *"[These terms are] not things that have been, like, defined. And usually the thing we all fall back on is the Civil Defence and Emergency Management Act or the National Group Plan or the Guide to the Group Plan and those things are not described there… and they're also not described in things like the National Disaster Resilience Strategy. And so, yeah, I can imagine everyone's got a slightly different [view]."*

Interviewee I:

> *"…So this is what I see and yeah, these [terms] are not being outrightly described in the Building Act. So yeah. There are natural hazards. Definition of natural hazards is quite streamlined in the Building Act [but] it's quite different in the RMA..."*

Interviewee H:

> *"So we, you know, at the moment we're going through a process of doing our own regional risk assessment profile to inform our Group Plan…. in the advice that we are given from the National Emergency Management Agency, it said you should incorporate the cascading nature of hazards or the multi hazard or operating in a multi hazard environment into your risk assessments. But no actual advice as to **how**."*

'**Cascading hazard**' was understood to be the more specific of the two terms. Concepts related to cascading hazard were described with a specific focus on the relational and connected aspects of risk, particularly impact and vulnerability. Within this relational framing, participants most often described these conceptual groupings:

- A **simple cascading hazard event**, which describes a specific event scenario such as an earthquake causing a tsunami;
- A series of **linear cascading hazard impacts**, which refers to a focus on the consequences of the event (with a particular focus on system vulnerabilities, understood in simple linear terms as 'domino effects' where subsequent events are each triggered by the one before);
- More **complex hazard cascading hazard impacts,** which refers to a more detailed focus on system vulnerabilities and unique circumstances; and

- **Compounding hazard impacts,** closely related to the above concept, but with the recognition that vulnerability may not be directly related to the initial hazard event and can be compounded or 'amplified'.

The frequently used term '**multi-hazard'** was most commonly understood by interviewees to be an overarching term that simply means 'more than one hazard', and thus incorporates cascading hazards. In addition to cascading, there were three other conceptual groupings articulated within multi-hazard discussions:

- An awareness of all latent hazard risks that exist in the physical environment
- All potential hazard events that could be caused by these risks (which includes an understanding of existing vulnerabilities), and
- Situations where there may be independent but concurrently occurring hazard events.

The graphic (Figure 3) below illustrates the range of concepts described by participants.

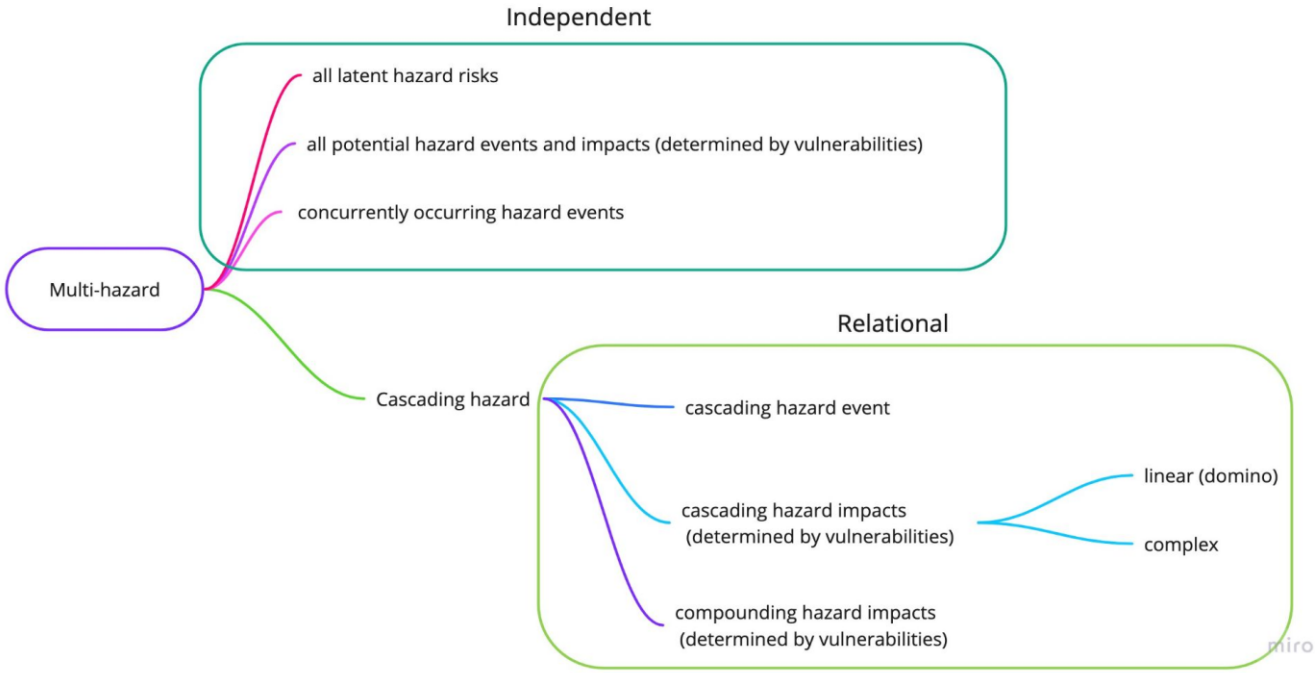

Figure 3: Visualisation of 'multi-hazard' and 'cascading-hazard' concepts described by participants.

While these are broad conceptualisations that participants described when discussing their understanding and use of terminology, it was also clear that the terms were sometimes used interchangeably with shifts of meaning dependent on professional context. For example,

Interviewee H suggested that different phases of the emergency management cycle (i.e. reduction, readiness, response, recovery) might influence application and use of the term ‘multi-hazard’.

Interviewee H:

> *“...I guess in a lot of ways they mean slightly different things depending on what [emergency management] phase you're in because in that readiness phase when we talk about operating in a multi hazard environment , we're talking about not being able to concentrate on hazards as single entities…but the [response] planning phase where we talk about yeah having a multi hazards approach ... it's more about the impact that these things **would** have collectively on a response as opposed to just the impacts of a volcano or just the impacts of a earthquake… So it is related to that response phase but it is more about making people think about impacts rather than hazards I guess.”*

A consistent theme is that the professional application of cascading hazard terminology emphasises the relational and connected aspects of hazard events, with a ‘domino effect’ or linear event chain often being referenced.

Interviewee D:

> *“Multi-hazard I guess to me is a situation where a property, a community, a region, faces multiple hazards. [They can] be concurrent and can occur at the same time... Now, cascading is where one causes another [then] causes another.”*

Another consistent theme is that cascading hazard terminology places a particular focus on social impact and vulnerability. Participants recognised connections between physical hazards but did not always consider a cascading definition to be appropriate for those connections. When thinking of ‘cascading’ hazard terminology, participants generally discussed ideas around the connections between impacts and consequences.

Interviewee H:

> *“They're often used interchangeably, aren't they? But to me they're slightly different in that multi-hazard could be an event that has multiple components that could impact in different ways, but kind of in the same time frame, whereas cascading hazard it's almost like that dominoes , to use a trope that's often quoted, when they're talking about cascading things and it's kind of that domino effect . So an example of a multi hazard could be the Hikurangi subduction zone earthquake, where the tsunami [is] the same time, you know, closely associated with that. Whereas [an example of a] cascading hazard could be something that causes a lifeline utility failure which causes hardship for communities further down the track, which causes a lack of water.”*

Interviewee B:

> *"...from a say, an earthquake point of view, a lot of our information I specifically deal with is either fault surface rupture, and how to mitigate that, or liquefaction, which I mean, if you wanted to get [into the] technical space you could almost call that a 'cascading hazard' from earthquake shaking, you know, but I probably wouldn't call it that. I would just say it's liquefaction hazard."*

Participants also discussed compounding impacts with increased levels of complexity and focused on situations where changing conditions or circumstances had the potential to increase vulnerability and risk. These were also described as 'amplification' factors.

Interviewee F:

> *"... the cascading thing to me is the fact that once you have an event and then you have another event, then it amplifies the impact of the second or the first."*

Interviewee G:

> *"I would almost call our summer planning [i.e. emergency management contingency planning allowing for increased visitation to holiday destinations during summer months] 'cascading' because we're starting with instead of our usual resident population, we can have another 100,000 people."*

Summary of key findings:

- Participants noted that they are not using formal definitions of the terms 'multi-hazard' and 'cascading hazard', and that they predominantly draw their definitions from their own experience of application within their professional contexts.
- Application and use of terms may differ depending on the professional context or even the emergency management phase, e.g. land use management decisions vs. emergency management and emergency readiness vs. response planning.
- 'Multi-hazard' is considered to be the overarching term which encompasses applications of both connected and unconnected hazards and risks.
- The 'multi-hazard' term use appears more often associated with the physical natural hazard space, while 'cascading' terminology is used to describe concepts that link hazards through to risk, vulnerabilities, consequences and impacts with focus on the potentially complex interactions between those factors.

4.3 Role context

Research participants were professionals drawn from different areas within the New Zealand risk reduction sector, including technical specialists, emergency management professionals, and local and central government staff. To understand the context of their roles, participants were asked to describe the kinds of work they were undertaking, including the **decisions they were making or influencing** in relation to risk reduction and **their interaction with** multi-hazard or cascading hazard information. Participants were largely focused on providing **information and advice**, often in statutory land use management and regulatory system settings, as well as working across different functions of emergency management including response planning roles and direct community interface work.

In a general sense, participants recognised that risk reduction mandates sit with different professionals, working across organisations which interface with each other and play specific roles influenced by legislation. As with the lack of consistently applied hazard terminology, this was seen as complicating decision-making using multi and cascading hazard and risk information, particularly as no agency has a mandate for overarching coordination.

Interviewee C:

> *“There's no one agency or profession that sort of takes the lead on [risk reduction], you know, there's the Building Act [administered] through MBIE, there's the CDEM Act [administered] through NEMA. There's the Resource Management Act [administered] through MFE. You know they all have a role and there's the role of insurance in this as well.”*

One function common across all participants was that of being a translator of technical information received from a variety of different sources (e.g. historical collected data, council records, Government reports, data from research institutes and Metservice, findings from universities, reports commissioned from private companies etc.). The translation role is an informal one that involves first understanding, then communicating, the significance of information to influence decision-makers. This role often involved communicating information from technical reports containing projections, modelling, scenarios and potential event impacts or consequences, as well as appropriate mitigation actions. While none of the participants directly referred to this function using the words ‘narrative’ or ‘story’, the use of real-world examples, prose descriptions, and visual elements to communicate to stakeholders in a relatable way beyond just the delivery of data all strongly suggested that practitioners saw the importance of narrative techniques. This will be expanded on in Section 4.4 below.

Interviewee B:

> *"...so I see my role really as a translator of technical information into useful information for people."*

Interviewee H:

> *"I guess the biggest problem that we have is that people either operate in a multi-hazard environment or an impact based environment, there's very little kind of translation from one to the other, most of the time you get just information We are expecting a storm of X kilometre an hour winds to impact at this time, in this area' and we have to decide what the impacts of that might be."*

Many participants were involved with risk assessment and consequence planning which increased their abilities to communicate the relative significance of technical information. This was due to the process of analysing potential impacts of hazards, and potential consequences of those impacts. Often consequence discussions had been undertaken using collaborative processes bringing in a range of stakeholders from varied operating contexts and perspectives. These experiences heightened participants' awareness of the significance of hazard information and allowed them to make connections between hazard, risk, impact, and potential consequences when communicating multi-hazard and cascading hazard information. Risk assessment and consequence analysis were reported as being an increasingly important core activity for best-practice emergency management work, and it was noted that this aligned with NEMA's recently updated Director's Guideline for undertaking risk assessments (New Zealand Ministry of Civil Defence & Emergency Management, 2022).

Interviewee D:

> *"What we're interested in…is, what's going to happen? You know, what are going to be the impacts or consequences from this hazard or set of hazards? And how do we manage those? How do we provide the appropriate services to impacted communities? So I guess, we are ultimately looking for What are going to be the different sets of consequences that we see from hazards?'… it's very much taking a focus of [assessing] consequences of a hazard or a set of hazards across a number of key environments such as social, economic, built and natural environments. So [as] part of our CDEM [Civil Defence and Emergency Management] group planning process we're currently working through a number of workshops to review our hazards. And while we come up with a few scenarios for the hazards, it's much more about what are going to be the consequences."*

Another core theme across participants' roles, particularly those focused more closely with gathering and procuring technical hazard data, was that of influencing statutory processes, particularly land use management and regulatory planning. These staff spoke of finding and

feeding multiple types of hazard data into statutory processes (for example, a regional council working with a territorial authority to ensure that their district plan changes appropriately reflect flood risk) as well as trying to make this data accessible to wider audiences (such as putting together general materials for public education and public speaking).

With the exception of emergency management dedicated public interface roles, the function of sharing hazard-related information with the public, colleagues, and other decision makers was discussed by participants and generally viewed as beneficial. Participants were often trying to make data collected for a specific purpose (e.g., a land use management decision) accessible to wider audiences. However, tailoring hazard and risk information for wider audiences and uses was not viewed as a primary function, with participants carrying out these tasks to varying degrees.

Interviewee A:

> *"I think [public education is a part of my role] but it's also an ethic I've brought to the role as well. I mean, you can choose not to do that. but I think it's an important component of my role."*

Interviewee I:

> *"...So what is the council going to do to actually collate [hazard assessment reports produced for different purposes] and then make them available in a public forum? …You know, what [Councils are] asking… seems valid. But you know if [they] don't really collate them and then, you know, make them publicly available so that the next user can make use of it, then I think [Councils are] actually not, you know, doing the right thing."*

Summary of key findings:

- Despite a lack of clarity in legislation, participants saw that they had an important role in risk reduction, one which involved working with technical information related to multi and cascading hazards to support the reduction of risk.
- A key role in working with technical information was one of being a translator, where they might take information received from raw technical data and translate that into products that support stakeholders in their risk reduction decision-making.
- Most participants also played a role influencing statutory processes such as land use planning.

- While communication of hazard and risk information to the public was seen as beneficial, it was not viewed as a primary role or responsibility of most participants.

4.4 Identified themes

Interview participants reflected on challenges of working with multi and cascading hazard and risk information, from accessing data, to 'sense-making' and interpreting data, to supporting decision-making, and the importance of collaboration and communication tools to convey insights.

4.4.1 Access to data

A prerequisite for any analysis of hazard and risk information is that the required data exists, is accessible, and can be found and understood by whomever requires it. Interview participants reflected on their barriers to accessing and using technical hazard information, from the supply of locally relevant data, the quality of said data and the difficulty for decision-makers to engage with technical information.

Access to regionally specific information of a sufficiently high quality and relevance, including the expert advice and local insights required to make sense of it, was shown to be a particular challenge. Participants noted that often there was a limit to nationally available resources and expertise (for instance, with weather-related insight information) which contributed to perpetuation of an operating context where regions were seemingly stuck in a more reactive state of emergency response cycles.

Interviewee H:

> *"...We are pretty well resourced [compared to other regions]...we have access to more subject matter experts to give us information, but we still are just one of 16 CDEM groups that need that local [information]... So we're still relying on the same ultimate providers and we're still taxing the limited resources that they have at their disposal to put towards doing that pre-work that we need, to understand what the local impacts would be.*
>
> *The access of the regions to quality scientific advice to inform their planning is also a barrier, because oftentimes the national providers get caught up at the national level [looking] for national solutions and they don't have either the time or the funding to understand what the local nuance of hazard impacts would be. [It] kind of precludes the regions [from] being able to be anything other than reactive and responsive."*

Participants also noted that both the format and presentation of technical reports and the expertise of the readers of those reports have a downstream impact on the likelihood that the

insights generated within those reports will be received as intended and passed along to others who require them.

Interviewee A:

> *"…typically what happens in these processes is that a lot of time is spent crafting these long wordy reports with all the detailed information in it. My overwhelming experience is that often, and this is the same for strategies, you'll develop these reports, and then they just go on a shelf and no one reads them."*

Interviewee H:

> *"The provision of science advice across the sector is really uneven. And different groups have access to different levels of advice and guidance for both in and outside of emergency events. And that's a problem."*

Participants reported additional challenges regarding the interpretation and refinement of data in a manner that leads to high quality, fit-for-purpose hazard risk assessment, reflecting that efforts to quantify uncertainty could lead to over-analysis, to the detriment of decision-making under that uncertainty.

Interviewee D:

> *"...you've got all the uncertainties on the hazard side, but you've just got so much uncertainty on the asset side of things too, or incomplete data or whatever…That I didn't have a lot of faith in the outputs of the process… And it just seemed like a lot of money was going into trying to pin down the risk… you know 'quantifying the risk' when it's like, well, maybe that money would be better spent actually just mitigating the risk on less information."*

Summary of key findings

Participants identified many challenges related to the accessibility of information, including:

- The availability of the scientific data required to support decision making, especially relevant locally specific data,
- Access to the expertise needed to help make sense of that data, and
- The presentation of technical reports in a length and format that increases the likelihood that they will be read, understood, and shared by the recipient.

4.4.2 ‘Sense-making’ and interpretation of data

Participants spoke of a substantial part of their role being that of a “bridge”, or “translation”, between raw technical information inputs and decision-making guidance outputs. This ‘sense-making’ process requires them to first establish a firm understanding of the scope and relevance of the incoming data for themselves, weigh the likelihood and severity of an often-complex web of hazard risk, and examine that risk through their local context. This understanding then serves as the foundation of any guidance given or actions taken and is critical for effective communication of that guidance.

The research and thinking skills required to not only digest and understand a range of technical information, but also to hold it in one's mind to provide good hazard and risk advice to support decisions make this part of the practitioner’s roles a complex one, and one that presents a range of challenges to the participants.

Interviewee H:

> *“We're still doing a lot of the… sense-making is a good way to put it, in [understanding] local nuance and to understand what the local impacts would be, and yeah, if we don't get these things happen all that often, either you know, it's kind of, it's tricky. But if we think of the hazards that impact us most often – like weather and flooding – we still are missing a step that translates the hazard to the impact on a community.”*

In the multi-hazard and cascading hazard context, this ‘sense-making’ role requires participants to be keenly aware not only of the relevant technical data, but also of possible gaps between that data and local conditions as well as the ways in which hazards might compound on each other in that context, particularly in terms of understanding vulnerability of and impacts on the community. However, many challenges and pitfalls were noted in this process of distilling the potential risks and impacts from complex, compounding hazards into a digestible message, from the information-consuming habits of the audience to the magnitude of the hazards themselves.

Interviewee C:

> *“...when you're showing cascading hazards people think Oh, it's too much.’ You know, ‘Just give us one hazard at a time. This is.. this is too much.’ And yet we need to be thinking about the cascading hazards because like in Christchurch, we've got the ground shaking, the buildings fell down, hill slopes, hillsides fell down and we've got liquefaction and now we've got a new flood risk...If you presented it in the scenario people would go Pffft it's just way too complex.’ But that's reality.”*

Often, scientific information—especially quantitative data—that might be provided to describe the hazard or risk needs to be made sense of by the practitioners themselves as well as their ultimate audiences. This can be challenging without expert input and/or advice, so access to these advisors becomes a great benefit to the sense-making process.

Interviewee F*:*

> *"...we get regional warning system messages, and…you know, like, they keep coming out at the moment, We've got big swells' and it's like, you know, swell 3.5 metres with 10 second interval' or blah blah and I'm like…is that bad? or what does that mean? Like, you know, I don't know…4.5 is like a trigger to be worried, but when it does, and there have been 4.5, and I'm like, do we need to be worried now? because…we've been told that's kind of like, you know, not a great number! So like, even us, we need our [conversations with] engineers."*

Without this availability of expert advice, not only is incoming access to information restricted, but sense-making and further sharing of refined information products is curtailed. Participants observed challenges with personnel and human factors in the flow of information, noting especially the variability of capacity and capability across the country. This especially presents problems in a multi-hazard context, where cross-communication, collaboration, and the incorporation of multiple viewpoints are critical for understanding risk and vulnerability. The participant below had observed this variability of information-sharing at the local government level leading to information flow issues.

Interviewee I:

> *"One of the drawbacks that we as a [national organisation]...found out during this whole…change was…depending on the size of the local government [organisation], the resources, the capabilities and the expertise vary… [including] skills and expertise to understand the [regulatory] changes and [the] implications…and also [there was]...lack of communication within the Councils. [For example]...the regional planners and the district planners are not really talking to the building consent officials...You know, [they] have the information that [they] need, but [they re] not really, you know, making everyone educated within [their own] organisation."*

Experience, especially direct experience of event impacts and consequences, came through strongly as a valued factor that contributes to an organisation's ability to undertake sophisticated, complex hazard risk assessment. The lived experience of the COVID-19 pandemic as a different kind of disaster response was given as an example of a shared experience that helped improve professional practice around complex assessments of risk and

vulnerability by deepening both the theoretical and practical understanding of how to make sense of an event with such wide-ranging follow-on effects. This kind of first-hand experience with systems disruption is directly applicable to a multi-hazard context.

Interviewee D:

> *"Whether it's us as emergency managers or police or FENZ, you know, there are a lot of people in [our region] who have been exposed to a wider range of events. So I think it's probably opened their thinking to… Right, this is a fire. But, so what? What are the next consequences? What are the wider consequences of this? And I think COVID-19 was, you know, it was a good step change I think in how people thought, because it tested, you know, where we traditionally focused on, you know, physical damage and physical things and physical problems… because most of our hazards tend to cause, you know, physical damage and disruption. This wasn't – this was people, this was systems, this was capacity problems."*

Interview participants spoke of a deep and mature level of hazard consequence awareness and understanding as being a particular capability acquired through experience. This understanding was viewed as necessary to produce nuanced, effective, and evidence-based multi-hazard risk advice, as while those new to the sector may be able to quickly learn the different individual components of risk and vulnerability, the complexity that emerges from a real-world multi-hazard event necessarily takes time to be properly understood and appreciated.

Interviewee H:

> *"...I mean, the only way we can assess the risk is to do them independently, but acknowledge that, you know the compounding nature and the concurrent nature of these hazards may amplify the impacts of other hazards. And keep it in the back of your mind when you're doing your response, but also your planning for response. So. Yeah…I guess that's one of the more difficult things [and] it really comes with experience. So new people coming into the sector might not have an appreciation for [the complexity]. They'll understand the kind of concept of it, but… It's a really tricky thing to be able to do, to keep your mind in a couple of places at the same time when you're giving advice. And [think] about, you know, the impact of events and not forget anything."*

Participants noted that their first-hand experiences with major disaster events had led to a greater and more sophisticated awareness of potential disaster impact, particularly experiences associated with the 2010-2011 Christchurch earthquake sequence. This greater awareness was observed throughout stakeholder groups, including risk reduction decision makers and those involved in community readiness planning.

Interviewee B:

> *"...there has been a lot of major events in the last 15-20 years, which have hugely raised the profile [of potential disaster impacts]. I remember when I started in this job, just trying to convince developers to even undertake a liquefaction assessment was a battle. But after Christchurch, everyone was like 'ohh, it does actually happen. It's not just a thing in some geologist s imagination'."*

Interviewee F:

> *"...back in the day, we used to go Okay, well, now you know about our [top 5 physical] hazards and [go] make a plan. And there you go, see . But then Canterbury happened and we learned so much that we now go And then what?' And we talk about all the impacts. So then we talk about no electricity. Yeah, no power, might not be able to get hold of anyone having to evacuate. Can't get home. Being stuck at home while the shops are shut and schools are shut…There's the six hazards that we're bringing that up for on a, you know, a PowerPoint. And [we] go and this is what we actually have to plan for. So don't go planning for an earthquake. Go planning for this ."*

Experiences around the Christchurch earthquakes were shared by several participants, an event that, as with the COVID-19 pandemic above, afforded first-hand experience with the reality of the kind of complex systems disruption that is directly applicable to understanding how multi-hazard events have the potential to unfold. However, one professional did observe that the memory of the Christchurch earthquakes was appearing to fade now as well, particularly in the context of younger colleagues coming into the workplace, leading to a worry that this firsthand knowledge may be fading from national memory.

Interviewee C:

> *"Yeah, I think [Christchurch experience had an impact]... I think it does make it more real, although what I'm finding is [that] Christchurch was, you know, eleven years ago now. People don't really maybe appreciate, if they haven't visited Christchurch, if they weren't really connected to Christchurch, exactly what that meant…Only that something happened, that there was an earthquake in Christchurch and it was bad. But it's happened there now, so it won't happen again…"*

Summary of key findings

In relation to the processing and making sense of multi and cascading hazard and risk information, participants reported that:

- Their roles required them to serve as a translator to help decision-makers understand the connections between risks and what they mean, often drawing the connections from physical hazards to their potential impacts and consequences.
- A free flow of information and advice from experts across the sector is required, but that capacity and capability of expertise and information sharing varies across the sector.
- Previous first-hand experience of disaster events and their responses can play a pivotal role in understanding information, though that experience is not evenly distributed.
- The nature of hazard risk analysis always comes with uncertainty, and efforts to improve decision-making under uncertainty are preferable to spending excessive time trying to quantify it.

4.4.3 Supporting decision-making in the context of governance policies

The work of resolving the tension between the pace with which new learnings arrive (whether gleaned by research or lived experience) and the relatively slower cycle times of legislation, policy and planning was cited by participants as something that can have considerable downstream impact on their ability to properly support good decision-making, both at a national and a local level. Participants reported working in a reactive rather than proactive mode more often than they would like, while noting that systems are slow to change to take account of new information.

Both the learning legacies and policy updates are important for the multi and cascading hazard context, as such mechanisms have the potential to provide better mandate, direction, or even just documentation of guidance about how data might be collected, presented, or used to reduce risk.

Interviewee I:

> *“Yeah, for us…a lot of it has been quite retrospective in terms of trying to understand what the recent events have actually caused, and how can we be better prepared in the event, you know, in a future event. So…a lot of the things that we are trying to do are probably the catch up game’ if I'm being honest with you.”*

At the local government level, challenges were raised around long timeframes associated with current RMA land use planning processes required to integrate new technical information into system policy settings. This presents a significant barrier for effective consideration of multi and

cascading hazard information as there is essentially no RMA mechanism to ‘fast track’ new or emergent hazard information or changing risk profiles.

Interviewee H:

> *“...there's good guidelines for the likes of liquefaction and surface fault rupture, we're getting some better ones around landslide coming out so, yeah, it's just getting those processes in place and those provisions in place in district plans which can take quite a quite a long period of time to do. I know with the fault rupture hazard, the guidelines have been around for 20 years, almost, but there's still some districts that don't have provisions in their plans because, yeah, the planning cycle just takes so long, like the gears grind very slowly and I know some of the scientists have been a bit like Why are there not more provisions in District Plans?’”*

Even where new data analyses and ‘lessons learned’ were documented and led to recommendations for further hazard mitigation actions, participants noted challenges around making decisions to move forward, which can often be a highly charged subjective and political discussion.

Interviewee A:

> *“...the barriers are not so much around having…policies being able to account for cascading hazards. It's more about...the political appetite and will to have strong policy direction. Particularly when it comes to avoiding hazards. In high hazard areas, avoiding development. So, in the past, there have been...multiple times [where] we've haggled over tiny provisions within our plans which are quite strongly directive to…avoid development in high hazard areas…the bigger battle really is less about incorporating the multiple or cascading hazards and more around how you ‘appropriately manage’ the impacts from those with the policy settings. And the pushback will come from developers and landowners. And it will come from politicians who don't really want to ‘buy the fight’.”*

Relatedly, participants reported that the methods used for delivering information are subject to the biases of the recipient, including a common tendency to focus on worst case scenarios or scenarios they have most commonly experienced instead of keeping a focus on vulnerability to impacts. These biases especially come into play in a multi-hazard context where the range of possible outcomes is potentially much wider, with a higher degree of uncertainty.

Interviewee H:

> *“...We do kind of get a little bit sidetracked by those more common risks **or** the more catastrophic risks, you know, because they are shiny and they're like oh gosh, it'd be really terrible ... But there's just that gap in the middle. We either focus on the most*

common or the most destructive, and not necessarily the link in between of how does something that's common become more destructive?'"

Summary of key findings

Participants reported the following challenges with supporting effective decision-making:

- The slow cycle times of policy and planning processes mean that recent experiential learnings and new technical information are difficult to integrate, at both a national and a local level.
- Conversations about appropriate hazard mitigation are often politically sensitive, presenting substantial difficulties.
- Biases of practitioners and decision-makers, particularly a tendency to prioritise worst-case scenarios or those with which people have previous personal experience, play a role in determining the focus of risk reduction activity.

4.4.4 The importance of collaboration

Participants recognised and welcomed a maturing of the sector towards greater and more holistic connections being made between technical information, such as hazard model outputs and the wider discussions about 'what does it mean?' and considerations of potential consequences for communities, with a focus on vulnerabilities.

Another theme that emerged was the value of approaches which bring in a range of perspectives for collaborative planning in the pre-event risk reduction context as a way of breaking down and making conversations about complexity more accessible. These comments frequently arose while considering the application of a tool/method such as the cascading hazard relational diagram used as a conversation aid for interviews (see attachment). Participants discussed the value of opportunities to facilitate deeper thinking about not just hazards but complex multi-hazard scenarios, including their impacts and consequences, which are very difficult but important conversations to have.

Interviewee G:

" [Co-constructing a visual diagram could be useful] in the planning session. Yeah, developing it in the session as you go, like even if you just start right this is if we're going to have an earthquake and aftershocks, this is what we're dealing with.' And then right let's add in a storm' or let's add an [additional] 100,000 people' or 'And suddenly [we have] all these road closures'."

Participants articulated that for localised risk assessments (including and perhaps especially multi-hazard risk) to produce effective data, a broad range of stakeholders need to be involved in a collaborative process from early on to ensure the integrity of the data, including awareness of the wider social infrastructure and planning for what happens when these systems are impacted.

Interviewee D:

> *"...We don't take a blinkered view, we do, you know, but it's a bit like dominos, you know, there's one domino that sets things going, but then there's a number of cascading consequences that will fall out of it, and we certainly consider them all. And that's partly why you want to have a large workshop and get everyone together in one room so that you can actually explore what those downstream consequences and impacts are. You know, if you have too small a group, you're not going to think widely enough or understand how your societal infrastructure works."*

Participants were aware of the increased priority given to collaborative processes, particularly emerging developments for complex hazard risk assessment methodologies, however they also recognised that examples of best practice, and specific guidance about how to undertake and embed multi-disciplinary risk assessment outputs into risk reduction activity is less clear. A request was expressed for further practical support around how to effectively incorporate multi-hazard or cascading hazard concepts into risk assessment processes.

Interviewee H:

> *"It's very difficult when you talk about risk assessments. Risk assessments in a multi-hazard environment are really tricky because you're trying to rank individual hazards, whereas if a power cut happens after an earthquake or after a storm, it's actually a lot more impactful than if it's just a general earthquake or just [if] a general power cut happened. But we still haven't kind of come to a decision as a sector about how we deal with cascading risk and compounding risk."*

There was an observation that risk information coming out of sophisticated 'consequence analysis' work was generally not well integrated into decision-making, particularly wider council decisions around land use planning and regulation.

Interviewee D*:*

> *"...we're ending up with a nice long chain now, where it should go from the, you know, the hazard modelling, understanding the primary hazard, any coincident hazards or cascading hazards from it, to then understanding 'what are the consequences on our environments?'*

> *You know, the built, the economic, the social, the natural, which is where we start playing with that interface between things that can happen to communities and how it actually impacts them, which will then go on to, well, 'What arrangements and processes and systems do we need to put in place to manage them?'…one of the things that's really challenging from a CDEM group perspective is [that] we're responsible for all that sort of consequence analysis [work]. Supporting communities to get ready and respond to and recover from [disaster events], but we don't actually have any good levers to manage risk reduction. All those levers actually sit with local authorities and regional councils."*

A desire for greater collaboration and information sharing was also reported by participants, as well as the need for a stronger 'multi-agency approach' between organisations working to reduce hazard risk, and ideally a better risk reduction relationship between central and local government.

Interviewee I:

> *"I think one of the fundamental points that we still are failing to address, you know, is a multi-agency approach in communicating the risk. Right. We often think about, okay, you know, the Building Act, the building regulator, yeah, land use planning, So it's the RMA, so that's the Ministry for the Environment. But we also have other key research entities and crown entities like EQC [who are] investing heavily into hazards and resilience, they have access to a lot of information that, you know, other ministries may not have... what we're missing at the moment is that key partnering up, you know…I would really love to see some, you know, some more coordination and also [more collaboration between] local government and central government."*

Summary of key findings

Participants reported the following challenges around collaboration:

- Participants valued a range of perspectives in collaborative planning in the pre-event risk reduction context and found this to be a way to make conversations about complexity more accessible.
- There is a lack of guidance to supporting multi and cascading hazard risk assessment and consequence analysis work, considering best practice approaches.
- While there is increasing sophistication in the quality of collaboratively developed risk information, it is still difficult to integrate outputs into wider risk reduction activity.

- There is no lead organisation to coordinate a multi-agency risk reduction approach for New Zealand. This results in uneven coordination and there is room for improvement for central and local government collaboration.

4.4.5 Communication tools

Participants employed a range of narrative, visual, and geospatial techniques and tools developed over the course of their careers to effectively communicate hazard information.

The importance of appropriate 'scene-setting' and providing a 'scaffold' around hazard information being presented was seen as a critical foundation for the effective delivery of information and guidance. Participants emphasised the value of taking the time to provide a detailed and comprehensive overview of the 'scene' before getting into the 'story'.

Interviewee B:

> *"I learned really early on from one of my mentors that when you put a map up, you've really got to set the scene and say, you know, so here's… you know like often someone might just put that map up and go ohh so you can see, there blah blah blah' but, you've really got to be like right, also –so this is Lake Rotorua, and you know here's Makoia Island and here's Rotorua CBD down here'—you've actually really got to set the scene for people."*

Participants also conveyed an awareness and recognition of the audience's need to understand the rationale or 'backstory' for the new information being presented to make sense and be accepted.

Interviewee F:

> *"And I guess it's always been helpful to be able to explain why it is that those areas are red. And it could be your ground is particularly hard' or there's, you know, a bridge here which would have to be fixed before they could get to this place to do this work Therefore, that's why, etc.', you know, but having the story to tell is quite important, because otherwise you re just, you know, putting yourself in this tricky situation, you got to be kind of mindful [that] having good stories to tell and good explanations for things are quite critical."*

One participant gave the following example of setting a simple story or scenario in the context of readiness planning to help visualise tangible impacts and consequences, rather than dealing in abstract concepts. This suggests how a narrative approach might be applied to a cascading

event in order to help decision-makers understand what hazards might be anticipated, and to guide people into thinking about how to approach it.

Interviewee G:

> *"…words like cascading event' [are] not fully understood. But if you said, right, well we've got flooding, we've got these three events on, if we had an earthquake at this point, how would we deal with that?'"*

Participants acknowledged that storytelling is a powerful communication technique and spoke of the use of anecdotes and stories from prior disaster events as an effective tool in the context of readiness decision-making with stakeholders, echoing the importance of practitioners' experience that respondents raised earlier in Section 4.4.2. This included the need for professionals to have their own 'war stories' to speak to, which helped to provide authenticity and legitimacy.

Interviewee F:

> *"Every event that we've had, we can draw on. So it's definitely good, I think from my point of view, for my team to have been deployed to events in the response because it makes us credible. And it makes us more attuned to some of the nuances. The things that happen, and more. You know we might not have been there but someone would have talked about 'oh my god, this family' in the response. So you know, you're hearing about actual impacts on people, so you've got some sort of war stories which can be quite like storytelling, quite powerful, you know."*

However, participants stressed the need to be aware of and sensitive to the potential to inadvertently traumatise or talk in an inappropriately lighthearted manner about events that have severely psychologically impacted people.

Interviewee F:

> *"...There was a school hall [event] and we were talking about Canterbury earthquakes and blah blah, you know. And then afterwards, you know, in the chat afterwards, this person came up to me, he's like oh, I was in the Canterbury earthquakes and I don't know how many… I went to lots of community meetings in school halls just like this one. It's just brought it all back . [I said], Look, I'm so sorry. It's powerful learning for everyone else, but for you, it's just, like, reminding you of how it felt to be in a school hall, a community meeting, talking about the earthquake. You know, that difficulty you were going through' so, yeah, storytelling is good, but it's just, yeah, I have to temper a little bit with who might be in the audience."*

Professionals actively consider and adjust their language, visual representations, framing, and context to maximise effective knowledge transfer. Participants working across the emergency management ‘4 Rs’ of risk reduction, readiness, response, and recovery reflected on the fact that the language and framing of information needs to change according to how the information is to be used to make decisions.

Interviewee G:

> *“The communication is totally different in readiness and response, so in readiness you want, you know, you've got the time to explain you...you probably like I say would present information in a number of different ways. And you know, maybe a diagram, a map, verbally and then some text that people can take away and read later. But in response you don't have that luxury, so you want to be as direct as possible so that this [information is] just because it's of utmost [importance].”*

The power of visual communication for connecting quickly, meaningfully, and intuitively was noted across a wide range of internal and external audiences.

Interviewee A:

> *“...I think, and this is my direct experience, in dealing with the general public and politicians, managers. Anything visual like this... It's like the human brain just has an ability to interpret that very quickly and easily. As opposed to written diagrams and words.”*

In particular, participants pointed to those audiences’ strong connection with geospatial representations, as it builds on people’s sense of place to build strong engagement with the materials being presented.

Interviewee A:

> *“Just the way in which that data has been visualised from that geospatial connection to areas and places where you can relate to them, we know them.”*

Interviewee G:

> *“...It's also a way that pulls people in. If you've got a display and you've got lots of lovely maps with pictures and they go ohh, that's my place!’ suddenly you've got really good engagement.”*

The use of colours on maps and visualisations was mentioned specifically as a nuanced area of professional learning and reflection. One participant described reactions to a red-amber-green

colour scale that was used to show levels of potential seismic activity, and linked this to a potential conflict with preconceived interpretations of the way those colours are commonly used.

Interviewee B:

> *"...[it was] sort of red you know along [one part of the region] and then sort of going more into orange and green further away, which would result in the likes of [another part of the region] having a relatively sort of green colour, which then people interpret as it's fine! . And it's like ohh, actually this is not fine. it's actually not fine there, it's just not as bad as, you know, other parts of the region, but it's not actually fine. So I changed the colour ramp that we used to something that tried not to indicate sort of red or green or yellow [colours] because people will take that as bad, good, okay ."*

Summary of key findings

When delivering risk communication products to their intended audiences, participants have found that:

- Establishing a contextual 'scaffold' that sets the scene for the recipient and orients them to that scene is important for engaging their attention and focus.
- Narrative (storytelling) formats were found to be more effective than presenting raw factual data alone, and 'war stories' incorporating the relevant personal experiences of the participants and others are particularly engaging.
- Visual communication tools, especially maps that ground the recipient in a local context, help audiences quickly build connections to the conveyed information.
- It is important to consider and adjust the language used in different emergency phases and contexts.
- There are potential pitfalls in the way that design choices such as colour can strongly affect how visual communication tools are perceived.

4.5 Identified opportunities to support better decision-making

In the process of reflecting about how multi and cascading hazard and risk data is currently used to support decision making, participants spoke of opportunities to enhance decision making, including opportunities around greater knowledge sharing, approaches for dealing with uncertainty and some general thoughts about professional development.

Opportunities around **enhanced and more consistent technical advice** was a theme that participants mentioned, including the value of having skilled personnel leading conversations around robust pre-event hazard information with appropriate application of hazard modelling outputs and scenario-based planning tools. This relates to the reflection on the need for expert input and advice identified in Section 4.4.2.

Additionally, a specific theme emerged around opportunities to **uplift capability and professional approaches to understanding, talking about, and making decisions under uncertainty**. Including ways to contextualise model uncertainty, how to make decisions based on those models, and how to use scenario-based planning as a way of guiding decision-making under uncertainty.

Interviewee C:

> *"...Models are always wrong, they're never gonna be 100% right. But we need to, we need to make the most of that. We need to use it like a crystal ball and say Okay, this is what could happen. So how are we going to plan for that? And how are we gonna plan for it now?' And I think the modelling can really help us build some scenarios, and some visualisations that make it real."*

Interviewee H:

> *"Yeah. I mean, I think. With all scenarios, unless people [already] understand how scenario planning based planning works, the first thing you have to do is confirm the assumptions of the scenario. You know, are they still correct when the event happens…. there is an uncertainty if it's scenario based. But the interpretation of this to the decision maker by whoever's giving them this piece of information [is] really critical."*

Interv*iewee B:*

> *"…the tsunami [scenarios] are always interesting because there's a lot of uncertainty in that modelling because it can come in at so many different points in the modelling process and even just things that are beyond… not even in the model.… there's so many variables in determining what a tsunami might do, and what we're trying to do is package all that up into three nice little zones that are easily understood by people. So that's always a challenge…it depends what level of communication you're going for."*

Further exploration of ways to have better conversations about inherent uncertainties in models, and how to proceed to make decisions under uncertainty, are likely to improve the quality of multi and cascading hazard and risk informed decision making. This is particularly relevant as

models introducing additional hazard factors and cascading hazard connections will be producing a wide range of plausible hazard scenarios with complex sets of variables.

Another opportunity that many participants identified throughout their reflections was ways to **share stories and professional experiences as a risk reduction sector.** This relates to Section 4.4.2 where participants recognise that the ability to effectively undertake their roles requires deep levels of experience which is hard to quickly acquire as a newcomer. This also relates to an awareness that different regions can and should constantly be learning from each other's unique experiences to lift professional practice across the country.

Interviewee D:

> *"…this is something that we don't quite do a good enough job of in Emergency Management, telling our story after an event. And yeah, you know it's not just [our region]. Yeah, you know, we probably had a worse time of it than most over the past decade or more. But you know, there are other regions, you know, you've got Bay of Plenty with Edgecumbe floods and Whakaari White Island. You know, there are a number of other regions out there that have also had experiences. And this is where the value lies in talking about [those] experiences…The recipients have their mind open to the broader consequences and impacts and challenges, you know, how the initial hazard event may spawn a number of other implications."*

Relatedly, one participant recognised that this sharing of stories could be taken even further into a dedicated training package for the 'readiness' phase of emergency management, specifically, best practice approaches to talking about hazards and impacts.

Interviewee F:

> *"...So there's lots of function training, lots of focus by NEMA on developing, redeveloping packages and it's all very important and needed and I m glad that they're doing more…But there is no training for the readiness [phase of emergency management]. And talking to people about hazards and impacts. Nothing's provided. There's no, you know, no training."*

Summary of key findings

Additional opportunities participants identified to support better decision-making include:

- Ways to provide more enhanced and consistent technical advice, specifically related to technical model outputs and scenario-based planning.

- Increased capability and accepted professional approaches for how to make decisions under uncertainty, and guidance for how technical model outputs and scenario-based planning can support this.
- Finding and taking advantage of opportunities to share stories as a sector, particularly between regions, and potentially within emergency management training packages.

4.6 Summary

This chapter has discussed the results and observations from the data gathered through participant interviews. Five key themes were identified: access to data. ‘sense-making’ and interpretation of data, supporting decision-making in the context of governance policies, the importance of collaboration, and communication tools.

The terms ‘multi-hazard’ and ‘cascading hazard’ were discussed and explored with participants, and while there was not a uniform shared understanding of these terms, meaningful distinctions between the two were made, with ‘multi-hazard’ being the more general term and encompassing ‘cascading hazard’ which focused more closely on the relationship between hazard impacts. Participants noted a lack of formal or legislative definitions, relying instead on personal interpretations shaped by professional experience.

The context of the professional roles of the participants were explored, including distinctions, between ‘risk reduction’ and ‘risk assessment’ practices, engagement with statutory processes, and participation (or lack thereof) in communications and information sharing. Participants recognised their pivotal role in risk reduction, acting as translators of technical data and influencing statutory processes.

Participants faced multifaceted challenges, from balancing reactive and proactive decisions to navigating slow policy processes and political sensitivities. Collaboration hurdles were evident, highlighting the absence of guidance, difficulties in integrating risk information, and the absence of a lead risk reduction organisation for coordinated efforts. Effective risk communication emerged as a key theme, emphasising the importance of narrative formats, visual tools like maps, and language adjustments tailored to emergency phases. Challenges with accessibility of information, particularly the availability of local scientific data, emerged as obstacles.

The analysis presented in this chapter indicates that there are opportunities for improvement in the communication of multi and cascading hazard and risk information, including enhanced technical advice, increased capability for decision-making under uncertainty, the sharing of

sector stories, collaborative planning, incorporating local and social infrastructure contexts into risk assessment, and anticipating change in contexts over time. The following Chapter Five will discuss recommendations, including guiding principles to consider when sharing multi or cascading hazard or risk information. The recommendations are based on the learnings described throughout this chapter.

5. Discussion

5.1 Introduction

This chapter considers the overarching research questions, using the research data collected in light of literature findings. The primary research questions for this thesis include:

1) How do New Zealand practitioners understand and use multi and cascading hazard and risk information for disaster risk reduction purposes?

2) How can multi and cascading hazard and risk information be effectively communicated to aid disaster risk reduction decisions?

The research was conducted with the primary objectives of understanding the interpretation and usage of multi and cascading hazard and risk information; contextualising the roles of professionals in disaster risk reduction; investigating the application of narrative communication; exploring barriers and opportunities; and developing communication recommendations. This chapter examines insights into these aspects and recommends the use of a set of guiding principles (Section 5.4.1).

5.2 Understanding and usage of multi and cascading hazard and risk information

One of the primary objectives of this research was to explore how New Zealand practitioners comprehend and apply multi and cascading hazard and risk information for disaster risk reduction purposes. The findings revealed that professionals in this field exhibit varying and overlapping interpretations of these terms, often informed by their professional experiences. Furthermore, the meanings of ‘multi-hazard’ and ‘cascading hazard’ can change depending on the context, particularly which phase of the emergency management ‘4 Rs’ (risk reduction, readiness, response, recover) they pertain to.

5.2.1 Understanding of terminology

The research showed that participants understand ‘multi-hazard’ terminology in the context of describing natural hazards themselves, whereas ‘cascading hazard’ terminology is often understood and used to talk about more nuanced aspects of impact and risk, and more likely to be linked to concepts of vulnerability. The research findings indicate that New Zealand

professionals are evolving their vocabulary, and that this may be influenced by the climate change response, as this broadly aligns with hazard related language coming from the Intergovernmental Panel on Climate Change (IPCC) literature (IPCC, 2022). However, the meanings of the terms are fluid and overlapping depending on context, as previously observed by Zuccaro et al. (2018).

The IPCC discourse around ‘cascading impacts’ places emphasis on sequences of impacts resulting in physical, natural, social, and economic disruption (IPCC, 2022). Further literature suggests that ‘cascades’ are new vocabulary to talk about complexities associated with system failure, having recently emerged as a new ‘paradigm of disaster’ focused on the high dependency of infrastructure and networked systems that support society (Alexander & Pescaroli, 2019). This also aligns with Staupe-Delgado’s (2019) observation that the change in the UN’s definition of ‘disaster risk’ is moving to represent an increased focus on systems vulnerabilities. New Zealand professionals appear to be reflecting these complexities in their understanding of terminology, and increasingly focusing on vulnerability concepts in the context of ‘cascades’.

5.2.2 Desirability of consistent terminology

The fact that these terms are being professionally applied in New Zealand without fixed or shared definitions is not unexpected, as none of the major pieces of legislation discussed in Section 1.3 (RMA 1991; CDEM Act 2002; LGA 2002; Building Act 2004) explicitly define 'multi-hazard’ or ‘cascading hazard’, nor are there internationally agreed-upon definitions for the terms, as shown in Section 3.3 (United Nations, 2015; UNDRR, 2017; IPCC 2020; FEMA, 2021; IPCC 2022). Professional guidance from the New Zealand Ministry of Civil Defence & Emergency Management (2022) has suggested consideration of ‘cascading hazards’ when undertaking hazard risk assessments, and participants noted this does encourage collaborative approaches around hazard risk assessment. However, they also reported a lack of clarity about *how* to effectively undertake this work. The absence of consistent definitions for these terms is likely contributing to the lack of clarity that New Zealand professionals are experiencing.

Therefore, it may be useful for the wider New Zealand ‘risk reduction sector’ (which comprises professionals undertaking a range of roles, generally within local and central government in respect of the highlighted legislation in Section 1.3), to reach agreement on a shared set of definitions, as well as how they directly relate to existing legislative requirement of the RMA 1991 and associated policy statements, the CDEM Act 2002, the LGA 2002, and the Building

Act 2004. This could then be used as the basis of developing best practice guidance. Additionally, the National Disaster Resilience Strategy (Ministry of Civil Defence & Emergency Management, 2019) calls out the need to understand and account for complexity. A set of shared sector definitions could contribute to shared understanding of and approaches to dealing with that complexity.

However, the findings of this research do not conclusively lead to a recommendation that consistent definitions of these terms are of highest priority, although it may be helpful. Of greater importance is the need to understand *where* practitioners' legislatively mandated responsibilities might be driving tasks related to multi and cascading hazard and risk information, and most importantly, establishing clear expectations and guidance for *how* this information is expected to be produced and applied to specific functional tasks. Specifically, this includes:

- How to undertake a cascading hazard risk assessment
- When and how does collaboration with stakeholders occur
- How should multiple hazard modelling outputs be treated, and
- How should decision-makers 'triage' priority of competing risk.

Having a clarity of purpose and clearer guidelines in relation to cascading and multiple hazard and risk information across the wider scope of risk reduction roles was seen as more desirable than fixed sector definitions (although the latter may be helpful to enable the former).

5.2.3 Changes in meaning due to the '4 Rs'

A theme that emerged through the research was the extent to which the meanings of the terms 'multi-hazard' and 'cascading hazard' change for practitioners operating at different phases of emergency management: risk reduction, readiness, response, and recovery (the so-called '4 R's') (New Zealand Ministry of Civil Defence & Emergency Management, 2019). In the earlier phases, the concepts were seen to be applied more to physical hazard and risk, while the response phase was perceived as more aligned with impacts.

For example, land use planning decisions might need to consider the level of risk associated with allowing activities in a specific geographical area. This could include considering and combining a range of existing and newly commissioned hazard information to assess risk tolerances for different land uses. Conversely, emergency response decisions might require fast decision making considering all available current hazard and risk information (e.g. likely weather

impacts, existing vulnerable areas, unique situational factors) for purposes of gauging likely impacts and quickly prioritising response actions.

Any future efforts to establish consistent definitions for terminology will therefore need to be flexible enough to allow for the dynamic applications across the spectrum of the ‘4 Rs’. The potential malleability of terminology across the different phases of emergency management may create space for further confusion in the absence of clear guidance which would ideally include examples to show how these concepts are relevant and applied at the different phases of emergency management.

As it stands, terminology nuances should be acknowledged when producing and framing complex hazard and risk information. Assumptions around shared understanding of ‘multi-hazard’ or ‘cascading hazard’ should not be made and necessary groundwork is required to establish shared understandings of the scope of the hazard or risk information required, including the specific context of the information needed, the decision(s) it is intended to inform, and the questions that are likely to arise in the context of that decision-making (Doyle et al., 2019; Doyle & Becker 2022).

5.3 Effective communication of multi and cascading hazard and risk information

The second research question focused on the application of narrative communication as a risk communication tool, particularly for non-technical decision makers. Findings reveal that practitioners are using different elements of narrative communication to enhance the understanding and application of multi and cascading hazard and risk information; and that leaning further into storytelling-related principles and techniques will likely help with addressing the challenges inherent in the communication of these complex sets of information to support effective engagement and decision making (Dykes, 2020; Kreuter et al., 2007).

5.3.1 Understanding the audience and their context

The importance of understanding the context in which multi and cascading hazard and risk information will be used, and the nature of the audience itself, was widely recognised by participants. This aligns with the literature that suggests that context is a critical factor in effective communication and that there is a delicate two-way communication balance that needs to be struck between storyteller and audience in risk communication (Doyle et al., 2019; Vinnell

et al., 2023a). Participants spoke of how they adjust language and information based on the phase of emergency management (e.g. readiness vs response, which also relates to the nuances in meaning of the terms ‘multi-hazard’ and ‘cascading hazard’ and varying information needs observed across the ‘4 Rs’ of emergency management described above) and also of their attentiveness to the characteristics of the audience themselves, e.g. conscious of trauma or stress levels in particular situations.

Participants described the importance of the ‘sense-making’ process: understanding the audience’s needs, tailoring information (the story) with an emphasis on helping them make good decisions and evaluate (or at least cope with) uncertainties (Daniel, 2007). This two-way communication is a key factor in supporting effective decision making and can almost be regarded as a two-way relationship (Balog-Way et al., 2020).

5.3.2 Narratives

Literature shows that the use of stories engages with different parts of the brain than facts and statistics alone (Dykes, 2020). Storytelling offers a powerful means of conveying complex risk information and has been successfully used in that regard for public health, natural disaster, and industrial hazard risks, among others (Heath, 2019; Altshuler, 2022; Janssen et al., 2012; Shanahan, 2019). Participants’ experiences highlight the significance of using narratives to help make meaning (Czarniawska-Joerges, 2004) of technical data and understand real-world risks the data represents. There were examples given where participants were intuitively employing narrative techniques, such as using ‘war stories’ that incorporate personal experiences to talk about hazard impacts, and this resonates with the literature's assertion that narratives are known to be a highly effective way to engage audiences (Kreuter, 2007; Shanahan, 2019).

Participants acknowledged that the capacity and capability of experts is necessary for a free flow of information across the sector, and therefore the production of nuanced risk advice, but noted that capacity is currently often insufficient. A narrative-based approach may help address the challenges of quickly training practitioners in the complexity associated with real-world multi-hazard environments (Mangione et al., 2013).

In addition to the core roles associated with the provision of hazard and risk data, participants saw themselves as communicators. The role of ‘translating’ complex information for a range of audiences and purposes was repeatedly discussed. With the lens of narrative theory applied to risk communication (Corvellec, 2011), this allows us to think of the roles of ‘storyteller’ for

practitioners trying to communicate, ‘audience’ for the various end-users of the hazard and risk data, with the phased story and ‘plot’ relating to the nuances of hazard data, uncertainties, and plausible risk scenarios. Practitioners are grappling with the challenges of communicating the complexities inherent with multi and cascading hazards and their impacts and thinking about ways to package and deliver complex hazard and risk information as ‘stories’ in meaningful ways as part of their roles.

5.3.3 Centreing vulnerability… but mind the biases

Working from a point of view which centres on the most vulnerable parts of a given system can help to set up decision-makers with the clarity and priority they need to solve the most pressing problems (Brooks, 2003). However, participants stressed the need to cover the realistic range of possible outcomes without dwelling on particularly optimistic nor overly pessimistic scenarios (Weinstein, 1989; Solberg et al., 2010), given the many biases that people will bring to their understanding of the story being presented, especially in a multi-hazard context where the breadth of possible outcomes can be staggering, even if the most extreme outcomes are unlikely.

The literature indicates that people may become ‘overloaded’ in their relative perception of hazard risk when there is an increase in the number of hazard risks being discussed (Vinnell et al., 2023b). This introduces a potential communication pitfall whereby information presentation across multiple hazards could inadvertently be influencing a minimisation in risk perception (Paton & McClure, 2013; McClure, 2017). This reinforces the importance of being sensitive to the framing of hazard and risk information, leading with ‘why?’ which informs ‘what?’.

5.3.4 Collaboration

Participants could see the importance of ongoing collaboration, particularly in the face of creating and using increasingly complex information that needs to inform decision making occurring in different parts of the New Zealand risk reduction system as defined by legislation. The practitioners’ recognition of the need for ongoing collaboration reinforces findings from Crawford et al. (2018b) that showed the importance of using collaborative processes to co-develop hazard risk models. This is particularly relevant considering the findings stressing the importance of access to advice from a range of experienced experts in order to make sense of hazard and risk information as well as the current variability of access to that information and advice across New Zealand.

It is clear that for hazard or risk products (which deal with many uncertainties) to be useful for their intended purposes, they need to be developed using a solid foundation of collaborative dialogue, bringing in a wide range of experience to cultivate dialogue and social learning and increase the potential of research to effect change (Bieluch et al., 2017). However, it is also clear that this is easier said than done in practice (Thompson et al., 2017).

5.3.5 Access to data as a prerequisite to effective communication

Participants discussed their need for access to both data (in appropriate formats) and support to effectively collaborate and communicate. Participants wanted to see an increase in nationally-produced, regionally-specific high quality scientific data from those with capability, and for this to be consistently available for all regions. Participants understood this to be a prerequisite for collaborative local analysis and sense-making to inform risk reduction decision-making. They further noted that the current patchy provision of scientific data and 'sense-making support' was creating regional inequities. This mirrors a global trend of emerging 'data-poor' vs. 'data-rich' regions and the subsequent development of approaches to cope with data scarcity (Dang et al., 2019; Malgwi et al., 2019), which may, along with continued advocacy for data equity, be worth considering in risk reduction efforts as this challenge also plays out.

5.3.6 Visual communications seen as helpful

In terms of support to make sense of and communicate complex hazard and risk data, the importance of using visual communication tools, and especially maps, was well appreciated by participants to help ground audiences in a local context. This is important as it allows for audiences to quickly build connections with additional layers of new information. An engaging narrative, supported by data that is effectively visualised in a way that makes sense for the audience and discussion at hand will influence the decisions people make based on the data. (Dykes, 2020). Compelling visuals aid in enhancing comprehension and engagement generally, with maps and other visually presented hazard information having been shown to bridge the gap between perception and reality (Tufte, 1998; Khan, 2012), and of maps being seen as hugely powerful communication tools within the New Zealand strategic policy context (Crawford et al., 2018b).

The visual discussion prompts used in interviews with participants included a conceptual mapping of cascade impacts (generated for a specific scenario for planning purposes which highlighted relationships between geomorphic phenomena with a temporal aspect) as well as a

hazard scenario wastewater outage map (showing a specific wastewater network impact estimate, with a temporal aspect after a single hazard). The introduction of these two different examples of visual communication products helped participants to recall their experiences of using similar tools in their work. The more abstract conceptual map of the cascading relationships facilitated nuanced conversations about different aspects of complex hazard and risk, while the specific local based and singular hazard focused map allowed participants to reflect on their experiences of trying to use map-based approaches in the context of communicating complex multi and cascading hazard and risk information.

5.4 Challenges

The research also explored the challenges and opportunities identified by practitioners in considering multi and cascading hazard and risk information.

As most practitioners work within a legislative/government context, the challenges of the **political** landscape and the **long timeframes associated with policy change** were cited as particular difficulties. This was recognised as creating both general uncertainty as well as situations where policy guidance can be underpinned by outdated information, given changes in the hazardscape.

Practitioners also frequently mentioned the tendency of those in the sector to be working in a **reactive environment**, feeling constantly stuck in the response and recovery phases, while under-resourced in the risk reduction and readiness phases. This was seen as both a problem of capacity and of access to appropriate resources (including regionally specific data and expertise).

This **lack of capacity** can be based on a general **shortage of data, advice, and expertise**, but also manifests as an **inequality of resources between the regions**. Additionally, a related challenge is the fact that, while practitioners cited the importance of deep experience for understanding complex, multi-hazard risks and events, that experience is hard-won and there are **few opportunities for new or less-experienced staff** to gain those experiences.

While there is no controlling for which disaster events personnel might be exposed to, the issue of the **complexity of 'sense-making'**—that is, the skills required to take disparate data and modelling information, combine it with understanding of the needs of the recipient, and turn it into an appropriate communication product—might possibly be addressed through training and professional development around systems thinking in the New Zealand disaster risk reduction

context. This could potentially be useful for both the producers of information, as well as the practitioners making use of it. Similar concerted efforts might also help to cope with the aforementioned **biases of the recipient** (e.g., the tendency to focus on worst case scenarios).

All of these elements contribute to the gap observed between **strategy and policy discourse and operational practice in terms of an approach to cascading risk** (Pescaroli, 2018) and the **limited availability of methodologies** for approaching this challenge (Zuccaro et al., 2018).

There are opportunities to address many of these challenges through the upcoming revisions to national policy settings. This principally includes the upcoming RMA reform and replacement legislation, however there are also opportunities associated with the implementation of the National Disaster Resilience Strategy, as well as the delivery of hazard and risk information related actions within the National Adaptation Plan (in respect of the Climate Change Response Act).

5.5 Recommendations

Given the conclusions drawn above from the research and the supporting literature, these findings can be translated into practical recommendations for the disaster risk reduction sector. The following section outlines a proposed set of guiding principles to consider when sharing multi or cascading hazard or risk information to increase the relevancy and applicability of complex hazard information and supporting communication products.

5.5.1 Guiding principles

These principles include a mix of good practices for communication generally and guidance specific to the hazard and risk communication field. This list is not meant to be comprehensive, and further research (noted below) may be required to establish a complete list of principles. These principles are relevant across the spectrum from researchers producing hazard information as well as general providers of hazard and risk related information to support decision making.

Principle 1: Know the audience, anticipate their questions, and respect their responsibilities

When communicating any multi or cascading hazard or risk information, create an audience-appropriate scaffolding. This should be based upon as assessment of who needs to be informed

(including a prior reflection on the characteristics of this audience, and how that may influence their needs), the questions for which they will likely need answers, the decisions they will need to make, the phase of the emergency response and the timeframes for decision making (Vinnell et al., 2023a).

Principle 2: Build collaboration into the process to collectively answer "So what?"

When creating communication products, they will be enhanced by the involvement of a range of different stakeholders as early as possible. The focus of this collaboration should be to collectively make sense of the implications of hazard and risk data (the 'so what?'). The benefits of engaging with others early are twofold: first, it ensures that any of the communication products being produced are fit for purpose and will be suitable to answer the right questions in the appropriate context; and second, it offers opportunities to get as many perspectives as possible on potentially complex risks in the pre-event planning phase (Crawford et al., 2018b; Balog-Way et al., 2020; Doyle & Becker 2022).

Principle 3: Recognise the power of a good story

Stories have been established to be a very effective form of communication, with advantages including improved engagement and comprehensibility, emotional connection, memory retention, contextualisation, reduced complexity, and improved ability to influence behaviour (Fisher, 1987; Corvellec, 2011; Czarniawska-Joerges, 2004). When considering how to best convey information to the audience, recognise the power of a narrative story as a more effective way to structure information than simply providing 'raw data'.

For example, in the risk reduction phase of emergency management, hazard probabilities and asset condition assessments may become more meaningful when contextualised with scenario-based risk communication products describing a range of plausible futures, linking to events that have happened in the past, using geographic contexts known to the audience, and specifically linking example events and associated impacts (Dykes 2020; Kreuter et al., 2007).

Principle 4: Centre system vulnerability as part of the story

When considering how to best convey information to an audience, incorporate a point of view which centres the most vulnerable parts of a given system (Brooks 2003; Adger, 2006). Increasingly cascading hazards, events and impacts are being recognised in terms of high levels of interdependencies within systems (e.g. electricity, communications, supply chains etc) which calls for heightened awareness of critical dependencies and 'vulnerability paths'

(Alexander & Pescaroli, 2019). Working from a point of view which centres the most vulnerable parts of a given system can help to set up decision-makers with the clarity and priority they need to solve the most pressing problems that they face (which may be applicable across a number of potential hazard event situations). However, care should be taken to cover the realistic range of possible outcomes without focusing on particularly optimistic nor overly pessimistic scenarios, given the literature that shows how such approaches can be counter-productive over the long term, leading to fatalism and denial (Paton, 2019).

Principle 5: Incorporate well-designed visual communications into narratives

As has been well-established in the literature, information is easier to quickly process, understand, and retain when presented in visual and narrative forms simultaneously rather than in one or the other (Paivio, 1991; Dykes 2020). Visual content should follow best practices for graphic and information design (Tufte et al., 1998). Communications around hazard and disaster risk are shown to particularly benefit from geographic information such as maps, which allows users of those communication products to quickly make meaningful connections with their own local context (Doyle & Becker, 2022).

5.5.2 Broader recommendations for the hazard and disaster risk reduction sector

In addition to the principles above that were developed in response to the primary research questions, broader opportunities were identified during the interviews which could have potential to improve capacity and capability within the New Zealand risk reduction sector to deal more effectively with multi and cascading hazard risk reduction. These opportunities could be realised through activities and professional development offerings from agencies such as the National Emergency Management Agency (NEMA), as well as with advocacy and collaboration within the sector.

Recommendation 1: More professional development opportunities focused on matters of complexity and vulnerability

Research participants discussed their desire to see more Emergency Management professional development and support, specifically focused in the ‘pre-event’ phases of risk reduction and readiness, that addresses the multi hazard and cascading hazard and risk concepts of complexity and vulnerability discussed above. Participants had a desire to see practical tools and to know what ‘best practice’ or ‘good’ looks like; for example, case studies showing how a

multi or cascading hazard risk assessment was undertaken, with a bigger focus on impacts and system vulnerability (Brooks 2003; Adger, 2006).

Recommendation 2: More opportunities for cross-agency collaboration

Cross-agency collaboration and the value of working together was a repeated theme identified by research participants, as was the recognition that more opportunities would be beneficial and likely enhance the quality of work within the sector, particularly new staff coming into roles. Participants already leverage off each other's skills and experiences but acknowledge that is often only possible due to their personal relationships. Therefore, more opportunities could be supported that allow for: professionals across risk reduction and readiness focused roles to connect; regular connections between different Emergency Management regional staff; connections between Councils and science advisers; and platforms for sharing experiences more widely across the sector (Doyle & Becker, 2022).

Recommendation 3: Improved data equity, including quality of and access to data

Access to hazard and risk (including vulnerability) data, and advice around the data, was identified as a challenge for participants, and it was recognised that access currently varies regionally, with more populous areas likely to be better served. As the current situation indicates inequities, it is recommended that more priority is given to resourcing providers of data to ensure that there are no regional disparities (Dang et al., 2019; Malgwi et al., 2019).

6. Conclusions and future research

The purpose of this research was to explore two main research questions:

1. How do New Zealand practitioners understand and use multi and cascading hazard and risk information for disaster risk reduction purposes?
2. How can multi and cascading hazard and risk information be effectively communicated to aid disaster risk reduction decisions?

To answer these questions, semi-structured interviews were conducted with practitioners working throughout the New Zealand disaster risk reduction sector. These practitioners work mostly in central and local government, with many of their functions heavily influenced by statutory mandates of key legislation such as the RMA, CDEM Act, Building Act, etc. These interviews were guided by the primary research objectives: to understand the interpretation and usage of multi and cascading hazard and risk information; to contextualise the roles of professionals in disaster risk reduction; to investigate the application of narrative communication; to explore barriers and opportunities; and to develop communication recommendations.

This research showed that practitioners have varying and overlapping interpretations of the terms ‘multi-hazard’ and ‘cascading hazard’, as these terms are not clearly defined in any of the relevant New Zealand legislation, and that the meanings of these words and their associated concepts can shift depending on context, specifically the phase of emergency management ‘4 Rs’ (risk reduction, readiness, response, recovery). This reinforced the importance of prior planning when communicating hazard and risk information, to clearly define the scope of required information, where that information will be needed, and who is being informed, as this will be prerequisite knowledge for creating the ‘right’ communication product.

Additionally, this research showed that there is nuance to the use of this terminology in New Zealand, with ‘multi-hazard’ more closely associated with the physical nature of natural hazards and ‘cascading hazard’ more often related to risk, impact, and systems vulnerability, and that a focus on systems vulnerability is increasingly important for risk reduction in New Zealand. Relatedly, while shared definitions may help strengthen shared understandings, practitioners indicated a greater need for specific practical guidance that can support shared understandings of **where and how** to apply multi and cascading hazard risk information within their roles. This includes the practicalities of undertaking complex risk assessments, when and how to bring in

collaborative approaches, what to do with multi-hazard model outputs, and how to deal with prioritising outputs from complex multi or cascading hazard risk assessment processes.

Outside of the scope of this research, but worthy of further exploration, would be an assessment of the value of standardised definitions for use in New Zealand. Future iterations of the National Disaster Resilience Strategy create a potential opportunity to capture shared definitions for these terms. This may have benefits, particularly if it encourages more guidance, collaboration and shared understanding around multi and cascading hazard risk assessment.

The research indicated that narrative techniques are a useful tool for risk communication worthy of further attention, particularly for articulating complex and/or uncertainty-heavy data and communicating with non-technical decision makers. Within this frame, the power and importance of visual communication was strongly reinforced. Findings showed that practitioners naturally employ narrative communication techniques to communicate multi and cascading hazard and risk information, and they have learned through trial and error how to effectively communicate with visual tools. The research showed promise in further exploring narrative or storytelling-related techniques to overcome the challenges of conveying increasingly complex risk information, including when and how to create and use visual products. Participants often saw themselves as performing a ‘sense-making’ role for their audiences and engaged in two-way dialogue in order to understand their needs and decision-making requirements and ‘triage’ complex information for them.

While this research contributes insights into hazard risk communication, gaps remain in the specific understanding of multi and cascading hazard and risk perceptions and communication approaches, particularly from a practitioner/professional perspective. An assessment of the effectiveness of hazard and risk communication in the face of multiple biases and challenges would be a promising avenue for further investigation.

Additionally, the literature on the general efficacy of the use of narrative techniques in disaster risk communication was found to be lacking relative to the number of individual case studies that have been published. Overviews of narrative risk communication are comparatively abundant in the public health space (Kreuter et al., 2007; Altshuler 2022) and while these studies had utility for this research, their findings still needed to be ‘translated’ from the public health sector to further explore how they may be applied within disaster risk reduction contexts.

Participants highlighted the myriad challenges with which they are grappling themselves, including navigating the balance of reactive and proactive decision-making, slow policy processes, political sensitivities, the lack of a lead organisation for coordinated risk reduction efforts, and disparities in access to data across regions.

The culmination of this research, complemented by insights from the supporting literature, yielded practical recommendations for the disaster risk reduction sector, encapsulated in a set of guiding principles to consider when sharing multi or cascading hazard or risk information in order to increase the relevancy and applicability of complex hazard information and supporting communication products:

1. **Know the audience, anticipate their questions, and respect their responsibilities.** Create audience-appropriate scaffolding based on an assessment of characteristics and needs, anticipate questions, and respect the responsibilities of decision-makers.
2. **Build collaboration into the process to collectively answer "So what?"** Maximise the early contribution of diverse stakeholders to collectively interpret hazard and risk data and discern the implications.
3. **Recognise the power of a good story.** Narrative approaches are effective in enhancing engagement, comprehension, and emotional connection. Stories that convey hazard and risk information in a contextualised manner can offer a more compelling structure compared to presenting raw data.
4. **Centre system vulnerability as part of the story.** Highlighting the most vulnerable parts of a system and acknowledging interdependencies and vulnerability paths within systems can improve risk reduction outcomes.
5. **Incorporate well-designed visual communications into narratives.** A simultaneous presentation of visual and narrative information is most effective for swift information processing, understanding, and retention. Geographic information, especially maps, is particularly suited to establishing meaningful connections with local contexts in hazard and disaster risk communication.

Beyond these guiding principles, the research identified broader opportunities that participants felt would improve the hazard and disaster risk reduction sector in New Zealand. Professional development tailored to complexity and vulnerability emerged as a need, with practitioners expressing a desire for practical tools and case studies illustrating best practices. Cross-agency collaboration was deemed essential, with participants advocating for more opportunities to

connect professionals across roles and regions, fostering knowledge exchange and collaboration. Additionally, addressing data equity challenges, specifically ensuring more uniform access to hazard and risk data, emerged as an area requiring further attention.

Overall, the findings of this research shed light on the intricacy of understanding and applying concepts related to multi and cascading hazard and risk in the context of risk reduction in New Zealand, a country with a significant hazardscape. With the volume of hazard and risk information increasing in parallel with the number of climate change induced disasters facing the country, the research also reinforced the need for clear communication in the face of this growing complexity. The lack of shared terminology highlighted the importance of establishing common ground in risk reduction discourse. The findings also underscored the challenge of simplifying multi and cascading hazard and risk concepts for effective communication, stressing a need to prioritise fundamental communication strategies.

The observation that individuals tend to stay within their own legislatively mandated domains within the New Zealand ‘risk reduction sector’ aligns with findings from Crawford et al. (2018b), emphasising the issue of compartmentalisation and thus the need for fundamentally collaborative approaches. Additionally, the need for precise audience targeting, as highlighted by Doyle et al. (2019), resonates with the notion of tailoring communication to specific contexts and stakeholders. The recognition of the critical role of visual communication aligns with previous research emphasising the importance of visual aids in conveying information, especially in the context of hazard and risk (Paivio, 1991; Dykes 2020).

The most novel findings from this research lie in the inherent current use of narrative techniques for sense-making by practitioners within the New Zealand risk reduction sector, as well as the emphasis on the influence of personal relationships and experiences in shaping their risk-related practices. Additionally, the insight that multi and cascading hazard and risk terminology takes on different meanings across phases of the ‘4 Rs’ adds nuance to the understanding of how risk-related language is used in New Zealand.

This research therefore shows the value of further exploring the application of narrative-based approaches and suggests that incorporating insights from broader communication studies may enhance the effectiveness of risk communication within the context of New Zealand disaster risk reduction. Moreover, this research recognises the important and challenging sense-making

roles currently played by New Zealand risk reduction professionals and identifies a need for further support of this critical role within the New Zealand disaster risk reduction sector.

References

Adger, W. N. (2006). Vulnerability. *Global environmental change*, *16*(3), 268-281.

AghaKouchak, A., Huning, L. S., Chiang, F., Sadegh, M., Vahedifard, F., Mazdiyasni, O., Moftakhari, H., & Mallakpour, I. (2018). How do natural hazards cascade to cause disasters? *Nature*, *561*(7724), 458–460. https://doi.org/10.1038/d41586-018-06783-6

Ajzen, I. (1991) The Theory of Planned Behavior. *Organizational Behavior and Human Decision Processes, 50*, 179-211. https://doi.org/10.1016/0749-5978(91)90020-T

Alexander, D. (2018). A magnitude scale for cascading disasters. *International Journal of Disaster Risk Reduction*, *30*, 180–185. https://doi.org/10.1016/j.ijdrr.2018.03.006

Alexander, D. W., & Pescaroli, G. (2019). What are cascading disasters? *UCL Open Environment*. https://doi.org/10.14324/111.444/ucloe.000003

Altshuler, R. D. (2022). Narratives Are Useful Strategies for Overcoming Challenges in Risk Communication. *American Journal of Public Health, 112*, S12_S14. https://doi.org/10.2105/AJPH.2021.306669

Atkinson, R., & Flint, J. (2001). Accessing Hidden and Hard-to-Reach Populations: Snowball Research Strategies. *Social Research Update*, *33*, 1–1.

Auckland Council. (2014). *Natural Hazard Risk Communication Toolbox.* https://www.civildefence.govt.nz/assets/Uploads/NHRCToolbox/NHRCToolbox-Auckland-Council.pdf

Auliagisni, W., Wilkinson, S., & Elkharboulty, M. (2022). Using community-based flood maps to explain flood hazards in Northland, New Zealand. *Progress in Disaster Science, 14.* https://doi.org/10.1016/j.pdisas.2022.100229

Bay of Plenty Regional Council. (n.d.), Natural Hazard Risk Assessment User Guide. https://atlas.boprc.govt.nz/api/v1/edms/document/A3889265/content

Berg, B. L., & Lune, H. (2017). *Qualitative research methods for the social sciences* (Ninth edition, Global edition). Pearson.

Bieluch, K. H., Bell, K. P., Teisl, M. F., Lindenfeld, L. A., Leahy, J., & Silka, L. (2017). Transdisciplinary research partnerships in sustainability science: an examination of stakeholder participation preferences. *Sustainability Science*, *12*, 87-104.

Biggs, D., Biggs, R. (Oonsie), Dakos, V., Scholes, R., & Schoon, M. (2011). Are We Entering an Era of Concatenated Global Crises? *Ecology and Society*, *16*(2). https://doi.org/10.5751/ES-04079-160227

Bodeker, G., Cullen, N., Katurji, M., McDonald, A., Morgenstern, O., Noone, D., Renwick, J., Revell, L. and Tait, A. (2022). *Aotearoa New Zealand climate change projections guidance: Interpreting the latest IPCC WG1 report findings.* Prepared for the Ministry for the Environment, Report number CR 501, 51p.

Braun, V., & Clarke, V. (2013). *Successful qualitative research: A practical guide for beginners*. SAGE Publications.

Brooks, N. (2003). Vulnerability, risk and adaptation: A conceptual framework. *Tyndall Centre for climate change research working paper*, *38*(38), 1-16.

Bryant, A., & Charmaz, K. (2007). Grounded theory research: Methods and practices. *The Sage handbook of grounded theory* (pp. 1-28). SAGE Publications.

Building Act 2004. https://www.legislation.govt.nz/act/public/2004/0072/latest/DLM306036.html

Cambridge University Press. (n.d.). Usurpation. In *Cambridge dictionary.* https://dictionary.cambridge.org/dictionary/english/cascade

Caribbean Disaster Emergency Management Agency (CDEMA). (2014). *Caribbean Handbook on Risk Management.* https://www.cdema.org/virtuallibrary/index.php/charim-hbook/what-is-charim

Chappell, P.R. (2014). *The Climate and Weather of Wellington Region*. NIWA.

Charmaz, K. (2013). *Constructing grounded theory*. SAGE Publications.

Charmaz, K. (2014). Grounded Theory in Global Perspective: Reviews by International Researchers. *Qualitative Inquiry*, *20*(9), 1074–1084. https://doi-org.ezproxy.massey.ac.nz/10.1177/1077800414545235

Charrière, M., Bogaard, T., & Mostert, E. (2012). Disaster managers' perception of effective visual risk communication for general public. In *Proceedings of the 8th international conference on geo-information for disaster management—best practices* (pp. 11-20). Enschede, the NetherLands: University of Twente.Civil Defence Emergency Management Act 2002. https://www.legislation.govt.nz/act/public/2002/0033/51.0/DLM149789.html

Clark-Ginsberg, A., DeSmet, D., Rueda, I. A., Hagen, R., & Hayduk, B. (2021). Disaster risk creation and cascading disasters within large technological systems: COVID-19 and the 2021 Texas blackouts. Journal of Contingencies and Crisis Management, 29(4), 445-449. https://doi.org/10.1111/1468-5973.12378

Climate Change Response (Zero Carbon) Amendment Act 2019. https://www.legislation.govt.nz/act/public/2019/0061/latest/LMS183736.html

Corbin, J., & Strauss, A. (2014). *Basics of Qualitative Research: Techniques and Procedures for Developing Grounded Theory*. SAGE Publications.

Corvellec, H. (2011). The narrative structure of risk accounts. *Risk Management*, *13*(3), 101–121. https://doi.org/10.1057/rm.2011.5

Crawford, M. H., Crowley, K., Potter, S. H., Saunders, W. S. A., & Johnston, D. M. (2018a). Risk modelling as a tool to support natural hazard risk management in New Zealand local government. *International Journal of Disaster Risk Reduction*, *28*, 610-619.

Crawford, M., Saunders, W., Doyle, E., & Johnston, D. (2018b, November 5–7). *End-user Perceptions of Risk Modelling End-user perceptions and use of natural hazard risk modelling across policy making, land use planning, and emergency management within New Zealand local government* [Short paper]. ISCRAM Asia Pacific 2018, Wellington, New Zealand.

Creswell, J. D., & Creswell, J. W. (2018). *Research design: Qualitative, quantitative, and mixed methods approaches*. SAGE Publications.

Cutter, S. L. (2018). Compound, Cascading, or Complex Disasters: What's in a Name? *Environment: Science and Policy for Sustainable Development*, *60*(6), 16–25. https://doi.org/10.1080/00139157.2018.1517518

Czarniawska-Joerges, B. (2004). *Narratives in social science research*. SAGE.

Dang, H. A., Jolliffe, D., & Carletto, C. (2019). Data gaps, data incomparability, and data imputation: A review of poverty measurement methods for data-scarce environments. *Journal of Economic Surveys*, *33*(3), 757-797.

Daniel, T. C. (2007). Managing Individual Response: Lessons from Public Health Risk Behavioral Research. In *Wildfire Risk* (pp. 103–116). Routledge. https://doi.org/10.4324/9781936331611-13

Dibble, R. R., Nairn, I. A., & Neall, V. E. (1985). Volcanic hazards of North Island, New Zealand-overview. *Journal of geodynamics, 3*(3-4), 369-396.

Dizhur, D., Giaretton, M., & Ingham, J. M. (2019). Damage observations following the M w 7.8 2016 Kaikoura earthquake. In *Proceedings of the International Conference on Earthquake Engineering and Structural Dynamics* (pp. 249-261). Springer International Publishing.

Doyle, E., & Becker, J. (2022). *Understanding the Risk Communication Puzzle for Natural Hazards and Disasters.* https://doi.org/10.1093/acrefore/9780199389407.013.208

Doyle, E., Johnston, D., Smith, R., & Paton, D. (2019). Communicating model uncertainty for natural hazards: A qualitative systematic thematic review, *International Journal of Disaster Risk Reduction*, Volume 33, Pages 449-476, ISSN 2212-4209. https://doi.org/10.1016/j.ijdrr.2018.10.023

Dunant, A., Bebbington, M., & Davies, T. (2021). Probabilistic cascading multi-hazard risk assessment methodology using graph theory, a New Zealand trial. *International Journal of Disaster Risk Reduction*, *54*, 102018. https://doi.org/10.1016/j.ijdrr.2020.102018

Duval, T. S., & Mulilis, J. (1999). A Person-relative-to-Event (PrE) approach to negative threat appeals and earthquake preparedness: A field study. *Journal of Applied Social Psychology, 29*, 495-516. https://doi.org/10.1111/j.1559-1816.1999.tb01398.x

Dykes, B. (2020). *Effective data storytelling: How to drive change with data, narrative, and visuals*. John Wiley and Sons, Inc.

Eisler, R. (2012). *The Fukushima 2011 Disaster*. CRC Press.

El Hussein, M. T., Kennedy, A., & Oliver, B. (2017). Grounded Theory and the Conundrum of Literature Review: Framework for Novice Researchers. *The Qualitative Report, 22(4),* 1198-1210. https://doi.org/10.46743/2160-3715/2017.2661

Emergency Management Bill. (2023). https://www.legislation.govt.nz/bill/government/202w1w3/0225/8.0/d16197443e2.html

Federal Emergency Management Agency (FEMA). (2021). *IS-230.E: Fundamentals of Emergency Management.* https://training.fema.gov/is/courseoverview.aspx?code=IS-230.e&lang=en

Finucane, M. L., Alhakami, A., Slovic, P., & Johnson, S. M. (2000). The Affect Heuristic in Judgments of Risks and Benefits. *Journal of Behavioral Decision Making*, *13*(1), 1–17. https://doi.org/10.1002/(SICI)1099-0771(200001/03)13:1<1::AID-BDM333>3.0.CO;2-S

Fisher, W. R. (1987). *Human communication as narration: Toward a philosophy of reason, value, and action*. University of South Carolina Press.

Franconeri, S. L., Padilla, L. M., Shah, P., Zacks, J. M., & Hullman, J. (2021). The Science of Visual Data Communication: What Works. *Psychological Science in the Public Interest, 22*(3), 110-161. https://doi.org/10.1177/15291006211051956

Fuller, T. (2023). A Rare Tropical Storm Drenches Dry California, Leaving at Least 1 Dead. *The New York Times*, A14-A14. https://www.nytimes.com/2023/08/20/us/storm-hilary-flooding-california.html

Gadsden, S. (2023). *Climate Change and the New Zealand Insurance Industry*, https://www.frankrisk.co.nz/sylvia-essay

Geonet. (2023, October 23). *Earthquake statistics*, https://www.geonet.org.nz/earthquake/statistics_long

Gigerenzer, G., Hertwig, R., & Pachur, T. (2011). *Heuristics: The foundations of adaptive behavior*. Oxford University Press.

Gill, J. C., & Malamud, B. D. (2016). Hazard interactions and interaction networks (cascades) within multi-hazard methodologies. *Earth System Dynamics*, *7*(3), 659-679.

Glaser, B. G. & Strauss, A. L. (2017). *Discovery of Grounded Theory: Strategies for Qualitative Research* (First edition). Taylor and Francis.

Glavovic, B.C., Saunders, W.S.A., & Becker, J.S. (2010). Land-use planning for natural hazards in New Zealand: the setting, barriers, 'burning issues' and priority actions. *Nat Hazards* 54, 679–706. https://doi.org/10.1007/s11069-009-9494-9

Glegg, S. M. N. (2019). Facilitating Interviews in Qualitative Research With Visual Tools: A Typology. *Qualitative Health Research*, *29*(2), 301–310. https://doi.org/10.1177/1049732318786485

Grace, E. S., France-Hudson, B. T., & Kilvington, M. J. (2019). *Reducing risk through the management of existing uses: tensions under the RMA.* GNS Science. https://doi.org/10.21420/27S5-E538

Griffin, R. J., Dunwoody, S., Neuwirth, K. (1999). Proposed model of the relationship of risk information seeking and processing to the development of preventive behaviors. *Environmental Research, 80*, 230-245. https://doi.org/10.1006/enrs.1998.3940

Guest, G., Bunce, A., & Johnson, L. (2006). How Many Interviews Are Enough?: An Experiment with Data Saturation and Variability. *Field Methods*, *18*(1), 59–82. https://doi.org/10.1177/1525822X05279903

Hancox, G. T. (2008). The 1979 Abbotsford Landslide, Dunedin, New Zealand: a retrospective look at its nature and causes. *Landslides, 5*(2), 177-188.

Harrington, L. J., Dean, S. M., Awatere, S., Rosier, S., Queen, L., Gibson, P. B., ... & Otto, F. E. (2023). *The role of climate change in extreme rainfall associated with Cyclone Gabrielle over Aotearoa New Zealand s East Coast*. https://doi.org/10.25561/102624

Heath, R. L., Lee, J., & Lemon, L. L. (2019). Narratives of risk communication: Nudging community residents to shelter-in-place. *Public Relations Review, 45(1)*, 128-137. https://doi.org/10.1016/j.pubrev.2018.12.004

Howarth, J.D., Barth, N.C., Fitzsimons, S.J., Richards-Dinger, K., Clark, K.J., Biasi, G.P., Cochran, U. A., Langridge, R. M., Berryman, K.R., & Sutherland, R. (2021). Spatiotemporal clustering of great earthquakes on a transform fault controlled by geometry. *Nature Geoscience 14*, 314–320. https://doi.org/10.1038/s41561-021-00721-4

Infrastructure New Zealand. (2023). *Submission on the Ministry for the Environment s proposed National Policy Statement on Natural Hazard Decision Making discussion document.*

https://infrastructure.org.nz/wp-content/uploads/2023/11/INZ-Submission-on-proposed-NPS-NHD-final.pdf

Intergovernmental Panel on Climate Change (IPCC). (2020). *The concept of risk in the IPCC Sixth Assessment Report: a summary of cross-Working Group discussions.* https://www.ipcc.ch/site/assets/uploads/2021/02/Risk-guidance-FINAL_15Feb2021.pdf

Intergovernmental Panel on Climate Change (IPCC). (2022). Glossary. In *Climate Change 2022 – Impacts, Adaptation and Vulnerability: Working Group II Contribution to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change* (pp. 2897-2930). Cambridge: Cambridge University Press. https://doi.org/10.1017/9781009325844.029

Janssen, E., van Osch, L., de Vries, H., & Lechner, L. (2013). The influence of narrative risk communication on feelings of cancer risk. *British Journal of Health Psychology, 18*, 407-419. https://doi.org/10.1111/j.2044-8287.2012.02098.x

Janz, N. K., Becker, M. H. (1984). The Health Belief Model: A decade later. *Health Education Quarterly, 11*(1) 1-47. https://doi.org/10.1177/109019818401100101

Kahneman, D., & Tversky, A. (1972). "Subjective probability: A judgment of representativeness". *Cognitive Psychology. 3* (3): 430–454. https://doi.org/10.1016/0010-0285(72)90016-3

Kahneman, D., & Tversky, A. (1979). Prospect Theory: An Analysis of Decision under Risk. *Econometrica*, *47*(2), 263–291. https://doi.org/10.2307/1914185

Kahneman, D., Slovic, P., & Tversky, A. (Eds.). (1982). *Judgment under Uncertainty: Heuristics and Biases*. Cambridge University Press. https://doi.org/10.1017/CBO9780511809477

Keen, S., Lomeli-Rodriguez, M., & Joffe, H. (2022). From Challenge to Opportunity: Virtual Qualitative Research During COVID-19 and Beyond. *International journal of qualitative methods*, *21*, 16094069221105075. https://doi.org/10.1177/16094069221105075

Kerr, J., Thomson, G., & Wilson, N. (2023). *Cyclone Gabrielle joins list of Aotearoa NZ s sudden mass fatality events .* Prepared for University of Otago.

Khan, A. A., Rana, I. A., & Nawaz, A. (2020). Gender-based approach for assessing risk perception in a multi-hazard environment: A study of high schools of Gilgit, Pakistan. *International Journal of Disaster Risk Reduction, 44.* https://doi.org/10.1016/j.ijdrr.2019.101427

Khan, S., Crozier, M. J., & Kennedy, D. (2012). Influences of place characteristics on hazards, perception and response: a case study of the hazardscape of the Wellington Region, New Zealand. *Natural Hazards*, *62*, 501-529.

Kreuter, M.W., Green, M.C., Cappella, J.N. *et al.* (2007). Narrative communication in cancer prevention and control: A framework to guide research and application. *ann. behav. med. 33*, 221–235. https://doi.org/10.1007/BF02879904

Lawrence, J., Bell, R., Blackett, P., Stephens, S., Collins, D., Craddock-Henry, N., & Hardcastle, M. (2020). Supporting decision making through adaptive tools in a changing climate. *Practice Guidance on Signals and Triggers*.

Lawrence, J. H., Judy Lawrence, Allan, S., & Clarke, L. (2021). *Enabling coastal adaption: using current legislative settings for managing the transition to a dynamic adaptive planning regime in New Zealand.* https://ndhadeliver.natlib.govt.nz/delivery/DeliveryManagerServlet?dps_pid=IE79197244

Lecointre, J., Hodgson, K., Neall, V., & Cronin, S. (2004). Lahar-triggering mechanisms and hazard at Ruapehu volcano, New Zealand. *Natural hazards, 31*, 85-109.

Lindell, M. K., & Hwang, S. N. (2008). Households' Perceived Personal Risk and Responses in a Multihazard Environment. *Risk Analysis: An International Journal, 28*(2), 539–556. https://doi.org/10.1111/j.1539-6924.2008.01032.x

Lindell, M. K., & Perry, R. W. (2012). The Protective Action Decision Model: Theoretical modifications and additional evidence. *Risk Analysis, 32*, 616-632. https://doi.org/10.1111/j.1539-6924.2011.01647.x

Lipkus, I. M., & Hollands, J. G. (1999). The visual communication of risk. *JNCI monographs*, *1999*(25), 149-163. https://doi.org/10.1093/oxfordjournals.jncimonographs.a024191

Local Government Act 2002. https://www.legislation.govt.nz/act/public/2002/0084/latest/DLM170873.html

Local Government Official Information and Meetings Act 1987. https://www.legislation.govt.nz/act/public/1987/0174/latest/DLM122242.html

Lyons, N. (2007). Narrative Inquiry: What Possible Future Influence on Policy or Practice? In D. Clandinin, *Handbook of Narrative Inquiry: Mapping a Methodology* (pp. 600–631). SAGE Publications. https://doi.org/10.4135/9781452226552.n23

Malgwi, M.B., Fuchs, S., & Keiler, M. (2019). An adaptive regional vulnerability assessment model: Review and concepts for data-scarce regions. *Natural Hazards and Earth System Sciences*, 1-46.

Mangione G.R., Capuano N., Orciuoli F., Ritrovato P. (2013), Disaster Education: a narrative-based approach to support learning, motivation and students' engagement, *Journal of e-Learning and Knowledge Society, 9*(2), 129-152.

Marchezini, V. (2020). "What is a Sociologist Doing Here?" An Unconventional People-Centered Approach to Improve Warning Implementation in the Sendai Framework for Disaster Risk Reduction. *International Journal of Disaster Risk Science*, *11*(2), 218–229. https://doi.org/10.1007/s13753-020-00262-1

McClure, J. (2017). Fatalism, causal reasoning, and natural hazards. In *Oxford Research Encyclopedia of Natural Hazard Science*. https://doi.org/10.1093/acrefore/9780199389407.013.39

Ministry for the Environment (2023). *Proposed National Policy Statement for Natural Hazard Decision-making Under the Resource Management Act 1991.* https://environment.govt.nz/publications/proposed-national-policy-statement-for-natural-hazard-decision-making-discussion-document/

National Research Council (US) Committee on Improving Risk Analysis Approaches Used by the U.S. EPA. (2009). *Science and Decisions: Advancing Risk Assessment.* https://www.ncbi.nlm.nih.gov/books/NBK214617/

Natural and Built Environment Act 2023. https://www.legislation.govt.nz/act/public/2023/0046/latest/LMS501892.html

National Emergency Management Agency. (2022). *Developing a new Emergency Management Act*. https://www.civildefence.govt.nz/cdem-sector/legislation/emergency-management-bill/

National Institute of Water and Atmospheric Research (NIWA). (2023, October 23). *Climate Extremes*, https://niwa.co.nz/education-and-training/schools/resources/climate/extreme

National Policy Statement on Urban Development 2020. https://environment.govt.nz/publications/national-policy-statement-on-urban-development-2020-updated-may-2022/

New Zealand Ministry for the Environment. (2020). *National Climate Change Risk Assessment for Aotearoa New Zealand: Main report – Arotakenga Tūraru mō te Huringa Āhuarangi o Āotearoa: Pūrongo whakatōpū*. https://environment.govt.nz/assets/Publications/Files/national-climate-change-risk-assessment-main-report.pdf

New Zealand Ministry for the Environment. (2022). *Aotearoa New Zealand s first national adaptation plan: Table of actions. https://environment.govt.nz/assets/publications/climate-change/MFE-AoG-20664-GF-National-Adaptation-Plan-Table-of-Actions-WEB.pdf*

New Zealand Ministry for the Environment. (2022). *National Adaptation Plan Te mahere urutaunga a-motu. https://environment.govt.nz/assets/publications/climate-change/MFE-AoG-20664-GF-National-Adaptation-Plan-2022-WEB.pdf*

New Zealand Ministry for the Environment. (2020). *Reforming the resource management system. https://environment.govt.nz/what-government-is-doing/cabinet-papers-and-regulatory-impact-statements/reforming-resource-management-system/*

New Zealand Ministry of Civil Defence & Emergency Management. (2019). *National Disaster Resilience Strategy Rautaki a-Motu Manawaroa Aitua.* https://www.civildefence.govt.nz/assets/Uploads/publications/National-Disaster-Resilience-Strategy/National-Disaster-Resilience-Strategy-10-April-2019.pdf

New Zealand Ministry of Civil Defence & Emergency Management. (2022). *Risk Assessment: Guidance for CDEM Group Planning*. https://www.civildefence.govt.nz/cdem-sector/guidelines/risk-assessment-guidance-for-cdem-group-planning/

New Zealand National Party. (2023, 28 October). *National s 100 Day Action Plan.* https://www.national.org.nz/100dayplan

Niasse, N. (2023). Limiting Misleading ideas about the History of Grounded Theory Methodology. *International Journal of Qualitative Methods*, 22. https://doi-org.ezproxy.massey.ac.nz/10.1177/16094069221149486

Omer, H., & Alon, N. (1994). The continuity principle: A unified approach to disaster and trauma. *American Journal of Community Psychology*, 22, 273–287. https://doi.org/10.1007/BF02506866

Orchiston, C., Davies, T., Langridge, R., Wilson, T., Mitchell, J., & Hughes, M. (2016). *Alpine Fault Magnitude 8 Hazard Scenario*. AF8.

Padilla, L.M., Creem-Regehr, S.H., Hegarty, M. *et al.* (2018). Decision making with visualizations: a cognitive framework across disciplines. *Cogn. Research 3*, 29. https://doi.org/10.1186/s41235-018-0120-9

Paivio, A. (1991). Dual coding theory: Retrospect and current status. *Canadian Journal of Psychology / Revue canadienne de psychologie*, 45(3), 255–287. https://doi.org/10.1037/h0084295

Palm, R., & Carroll, J. (2018). *Illusions of safety: Culture and earthquake hazard response in California and Japan*. Routledge, Taylor & Francis Group.

Paton, D. (2013). Disaster resilient communities: Developing and testing an all-hazards theory. *Journal of Integrated Disaster Risk Management, 3*, 1-17. https://doi.org/10.5595/idrim.2013.0050

Paton, D. (2019). Disaster risk reduction: Psychological perspectives on preparedness. *Australian Journal of Psychology*, *71*(4), 327–341. https://doi.org/10.1111/ajpy.12237

Paton, D., & McClure, J. (2013). *Preparing for Disaster : Building Household and Community Capacity.* Charles C Thomas.

Peers, J. B., Lindell, M. K., Gregg, C. E., Reeves, A. K., Joyner, A. T., & Johnston, D. M. (2021). Multi-hazard perceptions at Long Valley Caldera, California, USA. *International Journal of Disaster Risk Reduction*, *52*, 101955. https://doi.org/10.1016/j.ijdrr.2020.101955

Perry, R. W. (2018). Defining Disaster: An Evolving Concept. In H. Rodríguez, W. Donner, & J. E. Trainor (Eds.), *Handbook of Disaster Research* (pp. 3–22). Springer International Publishing. https://doi.org/10.1007/978-3-319-63254-4_1

Pescaroli, G. (2018). Perceptions of cascading risk and interconnected failures in emergency planning: Implications for operational resilience and policy making. *International Journal of Disaster Risk Reduction*, *30*(Part B), 269–280. https://doi.org/10.1016/j.ijdrr.2018.01.019

Pescaroli, G., & Alexander, D. (2015). A definition of cascading disasters and cascading effects: Going beyond the “toppling dominos” metaphor. *Planet@Risk*, *3*, 58–67.

Pescaroli, G., Nones, M., Galbusera, L., & Alexander, D. (2018). Understanding and mitigating cascading crises in the global interconnected system. *International Journal of Disaster Risk Reduction*, *30*, 159–163. https://doi.org/10.1016/j.ijdrr.2018.07.004

Polit, D. F., & Beck, C. T. (2010). Generalization in quantitative and qualitative research: myths and strategies. *International journal of nursing studies*, *47*(11), 1451–1458. https://doi.org/10.1016/j.ijnurstu.2010.06.004

Potter, S. H., Becker, J. S., Johnston, D. M., & Rossiter, K. P. (2015). An overview of the impacts of the 2010-2011 Canterbury earthquakes. *International Journal of Disaster Risk Reduction, 14*, 6-14.

Quigley, M. C., Bastin, S., & Bradley, B. A. (2013). Recurrent liquefaction in Christchurch, New Zealand, during the Canterbury earthquake sequence. *Geology, 41*(4), 419-422.

Reñosa, M. D. C., Mwamba, C., Meghani, A., West, N. S., Hariyani, S., Ddaaki, W., & McMahon, S. (2021). Selfie consents, remote rapport, and Zoom debriefings: collecting qualitative data amid a pandemic in four resource-constrained settings. *BMJ Global Health*, *6*(1), e004193.

Resource Management Act 1991. https://www.legislation.govt.nz/act/public/1991/0069/latest/DLM230265.html

Resource Management Review Panel. (2020). *New Directions for Resource Management in New Zealand*. https://environment.govt.nz/assets/Publications/Files/rm-panel-review-report-web.pdf

Reyners, M. (1998). Plate coupling and the hazard of large subduction thrust earthquakes at the Hikurangi subduction zone, New Zealand, *New Zealand Journal of Geology and Geophysics, 41*:4, 343-354. https://doi.org/10.1080/00288306.1998.9514815

Robson, D. (2021). *Complex uncertainty: Long-term risk management decision making in New Zealand local government* (Doctoral dissertation, The University of Waikato).

Rubin, H. J., & Rubin, I. (2012). *Qualitative interviewing: The art of hearing data*. SAGE.

Saunders, W., & Kelly, S. (2021). The importance of mapping hazard and risk in the post-RMA planning world. *Planning Quarterly.*

Shanahan, E.A., Reinhold, A.M., Raile, E.D., Poole, G.C., Ready, R.C., Izurieta, C., McEvoy, J., Bergmann, N.T., & King, H. (2019). Characters matter: How narratives shape affective responses to risk communication. *PLOS ONE 14*(12), Article e0225968. https://doi.org/10.1371/journal.pone.0225968

Simpson, N.P., Adade Williams, P., Mach, K. J., Berrang-Ford, L., Biesbroek, R., Haasnoot, M., Segnon, A. C., Campbel,l D., Musah-Surugu, J. I., Joe, E. T., Nunbogu, A. M., Sabour, S., Meyer, A. L. S.,Andrews, T. M., Singh, C., Siders, A. R., Lawrence, J., van Aalst, M. & Trisos, C. H. (2023). Adaptation to compound climate risks: A systematic global stocktake. *IScience, 26*(2). https://doi.org/10.1016/j.isci.2023.105926

Slovic, P. (2000). *The perception of risk*. Earthscan Publications.

Sohn, W., & Kotval-Karamchandani, Z. (2023). Risk perception of compound emergencies: A household survey on flood evacuation and sheltering behavior during the COVID-19 pandemic. *Sustainable Cities and Society, 94*. https://doi.org/10.1016/j.scs.2023.10455

Solberg, C., Rossetto, T., & Joffe, H. (2010). The social psychology of seismic hazard adjustment: Re-evaluating the international literature. *Natural Hazards and Earth System Sciences*, *10*(8), 1663–1677. https://doi.org/10.5194/nhess-10-1663-2010

Solomon, S.. (2023, October 31). White Island volcano eruption: Whakaari Management found guilty of ‘astonishing’ safety failures. *The Guardian.* https://www.theguardian.com/world/2023/oct/31/white-island-volcano-eruption-whakaari-management-found-guilty-of-astonishing-safety-failures

Spatial Planning Act 2023. https://www.legislation.govt.nz/act/public/2023/0047/latest/LMS723550.html

Statistics New Zealand (2023, October 25). *Subnational population estimates (urban rural), by age and sex, at 30 June 1996-2023 (2023 boundaries)*. https://nzdotstat.stats.govt.nz/wbos/Index.aspx?DataSetCode=TABLECODE7981

Staupe-Delgado, R. (2019). Analysing changes in disaster terminology over the last decade. *International Journal of Disaster Risk Reduction*, *40*, 101161. https://doi.org/10.1016/j.ijdrr.2019.101161

Strübing, J. (2019). The Pragmatism of Anselm L. Strauss: Linking Theory and Method. In *The SAGE Handbook of Current Developments in Grounded Theory*. SAGE Publications. https://doi.org/10.4135/9781526485656

Sullivan-Wiley, K. A., & Short Gianotti, A. G. (2017). Risk Perception in a Multi-Hazard Environment. *World Development, 97,* 138–152. https://doi.org/10.1016/j.worlddev.2017.04.002

Tanner Jr., J. F., Day, E., Crask, M. R. (1989) Protection Motivation Theory: An extension of Fear Appeals Theory in communication. *Journal of Business Research, 19*, 267 276. https://doi.org/10.1016/0148-2963(89)9008-8

Thompson, M. A., Owen, S., Lindsay, J. M., Leonard, G. S., & Cronin, S. J. (2017). Scientist and stakeholder perspectives of transdisciplinary research: Early attitudes, expectations, and tensions. *Environmental Science & Policy*, *74*, 30-39.

Tonkin & Taylor Ltd. (2016)*. Risk Based Approach to Natural Hazards under the RMA.* https://environment.govt.nz/assets/Publications/Files/NPS_Natural-Hazards-Framework_FINAL-Report-TT-June-2016.pdf

Tufte, E. R., McKay, S. R., Christian, W., & Matey, J. R. (1998). *Visual explanations: Images and quantities, evidence and narrative.*

Tversky, A., Kahneman, D., & Slovic, P. (1982). *Judgment under uncertainty: Heuristics and biases* (Manawatū Main Collection (Level 2) 153.46 Jud). Cambridge University Press.

Tversky, A., & Kahneman, D. (1973). Availability: A heuristic for judging frequency and probability. *Cognitive Psychology*, *5*(2), 207–232. https://doi.org/10.1016/0010-0285(73)90033-9

Uma, S. R., Scheele, F., Abbott, E., & Moratalla, J. (2021). Planning for resilience of water networks under earthquake hazard: A case study for Rotorua District, New Zealand. *Bulletin of the New Zealand Society for Earthquake Engineering*, 54(2), Article 2. https://doi.org/10.5459/bnzsee.54.2.135-152

United Nations. (2015). *Sendai framework for disaster risk reduction 2015 - 2030.* https://www.preventionweb.net/files/43291_sendaiframeworkfordrren.pdf

United Nations Office for Disaster Risk Reduction (UNDRR). (2017). *Report of the open-ended intergovernmental expert working group on indicators and terminology relating to disaster risk reduction*. https://www.preventionweb.net/publication/report-open-ended-intergovernmental-expert-working-group-indicators-and-terminology

Vinnell, L. J., Becker, J. S. & Johnston, D. M. (2023a). *Overview of Behavioural Theories: Key Principles and Examples* [Unpublished manuscript]. Joint Centre for Disaster Research, Massey University, Wellington, New Zealand.

Vinnell, L. J., Hudson-Doyle, E. E., & Becker, J. S. (2023b). *Risk perception, attitudes, and behaviour in multi-hazard environments: An experimental survey* [Unpublished manuscript]. Joint Centre for Disaster Research, Massey University, Wellington, New Zealand.

Wallace, L. M., Webb, S. C., Ito, Y., Mochizuki, K., Hino, R., Henrys, S., Scwartz, S., & Sheehan, A. F. (2016). Slow slip near the trench at the Hikurangi subduction zone, New Zealand. *Science, 352*(6286), 701-704. https://doi.org/10.1126/science.aaf2349

Weinstein, D. (1989). Optimistic Biases About Personal Risks. *Science 246*,1232-1233. https://doi.org/10.1126/science.2686031

Wilson, C. J. N., Houghton, B. F., McWilliams, M. O., Lanphere, M. A., Weaver, S. D., & Briggs, R. M. (1995). Volcanic and structural evolution of Taupo Volcanic Zone, New Zealand: a review. *Journal of Volcanology and Geothermal Research, 68*(1-3), 1-28.

Witte, K. (1992) Putting fear back into fear appeals: The Extended Parallel Process Model. *Communication Monographs, 59*, 329-349.

Woolley-Meza, O., Grady, D., Thiemann, C., Bagrow, J. P., & Brockmann, D. (2013). Eyjafjallajökull and 9/11: the impact of large-scale disasters on worldwide mobility. *PloS one*, *8*(8), e69829.

World Bank (2023, October 25). *Population density (people per sq. km of land area) - New Zealand.* https://data.worldbank.org/indicator/EN.POP.DNST?locations=NZ&most_recent_value_desc=false

Zuccaro, G., De Gregorio, D., & Leone, M. F. (2018). Theoretical model for cascading effects analyses. *International Journal of Disaster Risk Reduction*, *30*, 199–215. https://doi.org/10.1016/j.ijdrr.2018.04.019

Appendix A - Interview Questions

45 minute interview

[Introductions, reiterate information sheet, confirm consent as per completed form]

1. Can you please describe where you work and your role within the systems that you work?
   Prompt - include discussion of the types of decisions that you are directly responsible for and other people s decisions which you influence (In the context of hazards, risks, and their impacts)

2. What do the terms ‘multi-hazard’ and ‘cascading hazard’ mean to you?
   Prompt - Ensure explicit articulation of each

3. Can you describe your current approach to using multiple or cascading hazard information in your work?
   Prompt - If they don t, why not?

4. Thinking about the decisions that you need to make, or those that you support with information and advice, what kind of hazard or risk information do you require?
   Prompt - Does this include hazards, risk, or impact/consequences, or all? And - discuss source, context and format

5. What barriers have you faced in the past, in terms of incorporating multi-hazard or cascading hazard risk information into your work?

I will now introduce two examples of different kinds of products which have been created to communicate aspects of multi/cascading hazard and risk.

For each product, can you please tell me your initial impressions; if this kind of product would be useful or not in the context of your work, and why?

Example one: AF8 cascade web *hazard/impact* [relational, conceptual]

Example two: Rotorua wastewater network impact modelling - *single impact* [temporal; spatial]

Appendix B - Information Sheet

Understanding how to communicate cascading hazard model outputs to aid disaster risk management and recovery planning

Information Sheet, October 2022

What is this research about?

This research is being conducted to fulfill the thesis requirement for a Master of Emergency Management degree through the Joint Centre for Disaster Research at Massey University and GNS Science.

This is a social science project seeking to gather perspectives of professionals who use or require cascading/multi-hazard risk information in the context of their work. This research is looking to better understand professional contexts and gather feedback and perspectives on different approaches to communicating cascading/multi-hazard information.

Who are you?

Sophie Lascarides is a research student at Massey University with an interest in social science factors of disaster risk reduction and climate change adaptation. Sophie has previously worked for local and central government in a range of policy and strategy roles. Sophie's research is being supported and supervised by Dr Julia Becker (Massey University), Dr Mary-Anne Clive and Dr Nicholas Pondard (GNS Science).

Contact details:

Sophie Lascarides
[redacted]

Julia Becker
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What is involved?

This research will be informed by a range of stakeholder interviews. Your involvement would be a one-on-one recorded online interview of approximately 45 minutes, conducted using zoom. You may also be invited to voluntarily participate in a follow up online survey later in the year, which would require no more than 20 minutes of your time.

What will be done with the information?

It is anticipated that your perspectives will contribute towards insight and recommendations for how cascading hazard model outputs can be communicated in a useful way that helps with risk reduction decision-making. In order to share these insights, it is possible research findings may be incorporated into an academic research article in addition to the primary academic thesis.

Interview recordings will be securely retained for the purposes of transcribing and analysing research findings only. Your contribution will be anonymised and generalised in the findings, so you cannot be identified in the research.

What are my obligations?

You are under no obligation to accept this invitation. If you decide to participate, you have
the right to:

- decline to answer any particular question;
- withdraw from the study (by 6 December 2022, before final write-up occurs);
- ask any questions about the study at any time during participation;
- provide information on the understanding that your name will not be used unless you give permission to the researcher;
- be given access to a summary of the project findings when it is concluded;
- ask for the recorder to be turned off at any time during the interview.

Please ask us if you would like any further information.

This project has been evaluated by peer review and judged to be low risk. Consequently, it has not been reviewed by one of the University's Human Ethics Committees. The researcher(s) named in this document are responsible for the ethical conduct of this research.
If you have any concerns about the conduct of this research that you want to raise with someone other than the researcher(s), please contact Professor Craig Johnson, Director (Research Ethics), email humanethics@massey.ac.nz.

Appendix C - Interview Consent Form

Participant Consent Form for Research - Understanding how to communicate cascading hazard model outputs

Please take the time to read the information sheet carefully, and consider whether you would be willing to take part in this research. Please contact the researcher if you would like more information.

I have read the Information Sheet and have had the details of the study explained to me. My questions have been answered to my satisfaction, and I understand that I may ask further questions at any time.

- I **agree** to the interview being recorded.
- I **do not agree** to the interview being recorded.

- I **agree** to participate in this study under the conditions set out in the Information Sheet.
- I **do not agree** to participate in this study under the conditions set out in the Information Sheet.

Participant name (printed):	
Role/Position title:	
Organisation:	
Signature:	
Date:	