The low-likelihood challenge: Risk perception and the use of risk modelling for destructive tsunami policy development in New Zealand local government

Miles H. Crawford[1]
Wendy S. A. Saunders[2, 3]
Emma E. H. Doyle[1, 3]
Graham S. Leonard[2]
David M. Johnston[1, 3]

[1] Joint Centre for Disaster Research, Massey University, New Zealand.

[2] GNS Science, New Zealand

[3] QuakeCoRE, New Zealand

Author correspondence:
M.H. Crawford,
Joint Centre for Disaster Research,
Private Box 756,
Wellington 6140
New Zealand.
Email: M.Crawford1@massey.ac.nz

URL: http://trauma.massey.ac.nz/issues/2019-1/AJDTS_23_1_Crawford.pdf

Abstract

The Hikurangi Subduction Interface, located 50 to 100 kilometres off the east coast of New Zealand's North Island, has the potential to generate the most destructive tsunami New Zealand is likely to encounter over a 1000-year timeframe. Yet, while such a severe risk hangs over the area, the number and detail of tsunami risk management policies do not match this risk. This article presents research on the influence of low-likelihood on perceptions for developing destructive tsunami risk management policy. It explores the thoughts and opinions of natural hazard risk practitioners in regards to tsunami risk management policy, along with the use of risk modelling (RiskScape) for tsunami policy development. Results highlight risk perceptions associated with the low-likelihood of a destructive tsunami, including such an event being perceived as "not happening here" and the development of tsunami risk management policy perceived as sitting in the "too hard basket"". We discuss how these risk perceptions could be influenced by cognitive biases due to their seemingly illogical nature and how risk modelling can be used as a communication tool to help overcome these perception challenges. We conclude with some recommendations for how we could better match tsunami risk management policy with tsunami risk through further developing local government provisions for risk management, the influence of cognitive biases, risk modelling, and policy flexibility.

Keywords: *Tsunami, risk perception, policy development, risk modelling, cognitive bias, local government*

The Hikurangi Subduction Interface is capable of producing an all-of-interface megathrust earthquake ranging in magnitude from M7.5 – 9.0 (Power, 2013). Figure 1 sets out the location of the Hikurangi Subduction Interface off the east coast of New Zealand's North Island, presenting how a tsunami generated within the interface could affect 200-300 kilometres of the nearby coast, potentially impacting on the Gisborne, Hawke's Bay, and Wellington regions, along with a small amount of the Manawatu region (excluded from this study). Table 1 provides the modelled median tsunami wave heights and direct losses, derived using the RiskScape model (King & Bell, 2005; King & Bell, 2009), that each of these regions could expect from a M9.0 rupture along the length of the Hikurangi Subduction Interface.

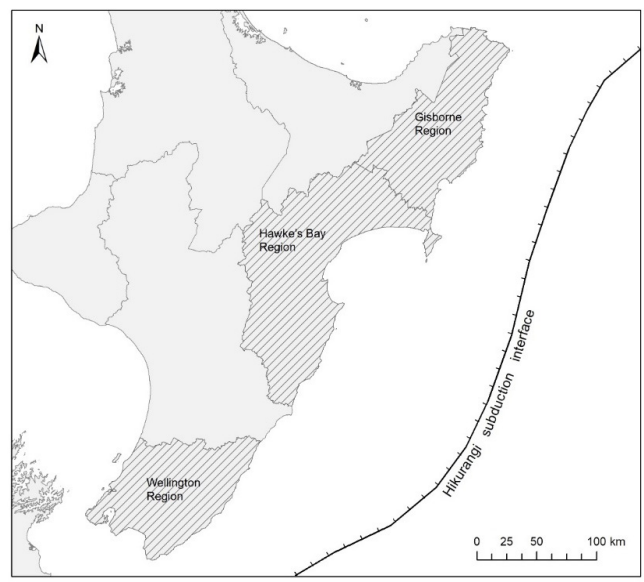

Figure 1. The Hikurangi Subduction Interface and the Gisborne, Hawke's Bay, and Wellington regions.

Table 1.
Modelled median wave height and direct losses from M9.0 rupture on the Hikurangi subduction interface.

Location	Wave height (m)	Deaths	Injuries	Economic loss ($m)
Wellington	7.4	2198	1792	5,556
Hawke's Bay	8.4	4895	3752	5,211
Gisborne	8.0	982	829	1,734

Note. Table adapted from Gill, Clough, and Webb (2015) and Horspool, Cousins, and Power (2015).

With such severe consequences impacting these regions, it is understandable that tsunami have been identified as potentially New Zealand's most severe natural hazard (Department of the Prime Minister and Cabinet, 2007). However, considering the comparatively high risk from tsunami, New Zealand spends relatively little on mitigation. This is evidenced in Table 2, which presents public spending on tsunami risk management compared to other risks.

Table 2.
Public spending on tsunami risk management compared to other risks.

Event	Government spending 2008/9, $m	Average annual individual fatality risk/100,000	Spending per unit of risk $m
Assaults	$122	1.3	$93.85
Workplace accidents	$85	4.1	$20.73
Vehicle accidents	$854	9.2	$92.83
Tsunami	$2.55	2.8	$0.910

Note. Table from Gill et al. (2015; p.4).

Our capacity to withstand and recover from the impacts of destructive tsunami is achieved through a combination of scientific research to build our understanding of the hazard and local government policy which enables the risk to be assessed, communicated, and managed within our communities. However, natural hazard risk management in New Zealand local government is challenged by a complex legislative environment, lack of data, misconceptions and biases, limited resources, and the differing requirements of numerous actors (Crawford, Crowley, Potter, Saunders, & Johnston, 2018; Glavovic, Saunders, & Becker, 2010; Kilvington & Saunders, 2016; Saunders, Grace, & Beban, 2014). While the devastating impacts of recent tsunami in the Indian Ocean, 2004, Samoa, 2009, Japan, 2011, and Indonesia, 2018, have raised awareness and spurred tsunami policy development (Johnston et al., 2014; King, 2015), local government has been slow to integrate such lessons into natural hazard risk management policy (Basher, 2016; Lawrence, 2018; Local Government New Zealand, 2014).

This research aims to understand how tsunami risk management policy and procedure relates to tsunami risk in Gisborne, Hawke's Bay, and Wellington. It explores practitioners' perceptions of low-likelihood, destructive tsunami, their views on tsunami risk management policy, and the use of risk modelling as a communication tool for tsunami risk management. The rest of the introduction describes the complex legislative structure for how tsunami risk management is achieved in New Zealand and introduces risk modelling as a communication tool for tsunami risk management. The method section explains the mixed method approach of qualitative interviews and document analysis used to gain a deeper understanding of practitioners' views on tsunami risk management policy distribution and how tsunami policy is corroborated by practitioners' perceptions of tsunami risk. The findings presented in the results section highlight a paucity of tsunami risk management policy across the study area and sets out three key themes that emerged from analysis of the qualitative interviews: disassociation from tsunami risk, reduced motivation for developing policy, and risk modelling challenges. Following these results, we discuss how cognitive biases associated with low-likelihoods influence tsunami risk perceptions and challenge motivation for tsunami policy development. We propose that risk modelling is a valuable tool that can help address this challenge. In the discussion section we also provide recommendations for how risk modelling can work in combination with risk management, cognitive debiasing techniques, and long-term planning to overcome the low-likelihood challenge for tsunami risk management policy development in New Zealand local government. However, we argue that before this is achieved, fundamental challenges for how natural hazard risk is governed need to be addressed.

Natural Hazard Risk Management, Tsunami Risk Management, and Risk Modelling in New Zealand

Natural hazard risk management. We view risk as "uncertainty about and severity of the consequences of an activity with respect to something that humans value" (Aven, Renn, & Rosa, 2011, p. 1074). Risk is managed through arrangements for designing, implementing, monitoring, reviewing, and continually improving activities for its control (International Organization for Standardization, 2009). When applied to natural hazard management in New Zealand, risk management

sits within a complex, interrelated system of devolved legislation (Local Government New Zealand, 2014). Figure 2 sets out the relationship across New Zealand legislation for the management of natural hazards.

Within this breadth of legislation, four key statutes provide a framework of responsibilities for how natural hazard risk management is applied:

1) The Local Government Act (LGA) – A local authority must manage risks to infrastructure from natural hazards (Section 101B (3)(e); New Zealand Government, 2002b).
2) The Resource Management Act (RMA) – A local authority shall manage risks for the use, development, and protection of resources (Section 6 (h); New Zealand Government, 1991).
3) The Civil Defence Emergency Management Act (CDEMA) – A local authority shall encourage and enable communities to achieve acceptable levels of risk (Section 3 (b); New Zealand Government, 2002a).
4) The Building Act (BA) – A local authority must manage consent for construction or alteration of buildings subject to natural hazards (Section 71; New Zealand Government, 2004).

While intending to work seamlessly together, each piece of legislation is applied through separate local government functions which often have limited integration and effectiveness for natural hazard management. This is reflected in Saunders, Grace, Beban, and Johnston's (2015) review of local government natural hazards management, where they note that collaborations across different natural hazard practitioner roles are not commonly encouraged for sharing information, good practice, and understanding of roles.

Tsunami risk management. Tsunami risk management sits within this challenging policy environment. While it would ideally be a joint responsibility across the local government land use planning, emergency management, and building control functions, it has historically sat within emergency management for application (Johnston et al., 2008; Johnston et al., 2014; King, 2015; Saunders, Prasetya, & Leonard, 2011; Webb, 2005). Webb (2005) explains that while all tsunami risk can be managed through land use planning arrangements, "due to a public desire to use coastal areas and the relatively long return period of damaging tsunami, regulations and land use planning are in reality unlikely to provide effective mitigation for the entire risk" (Webb, 2005, p. 64). As such, the residual risk is managed through a readiness and response approach of public education, warning, and evacuation

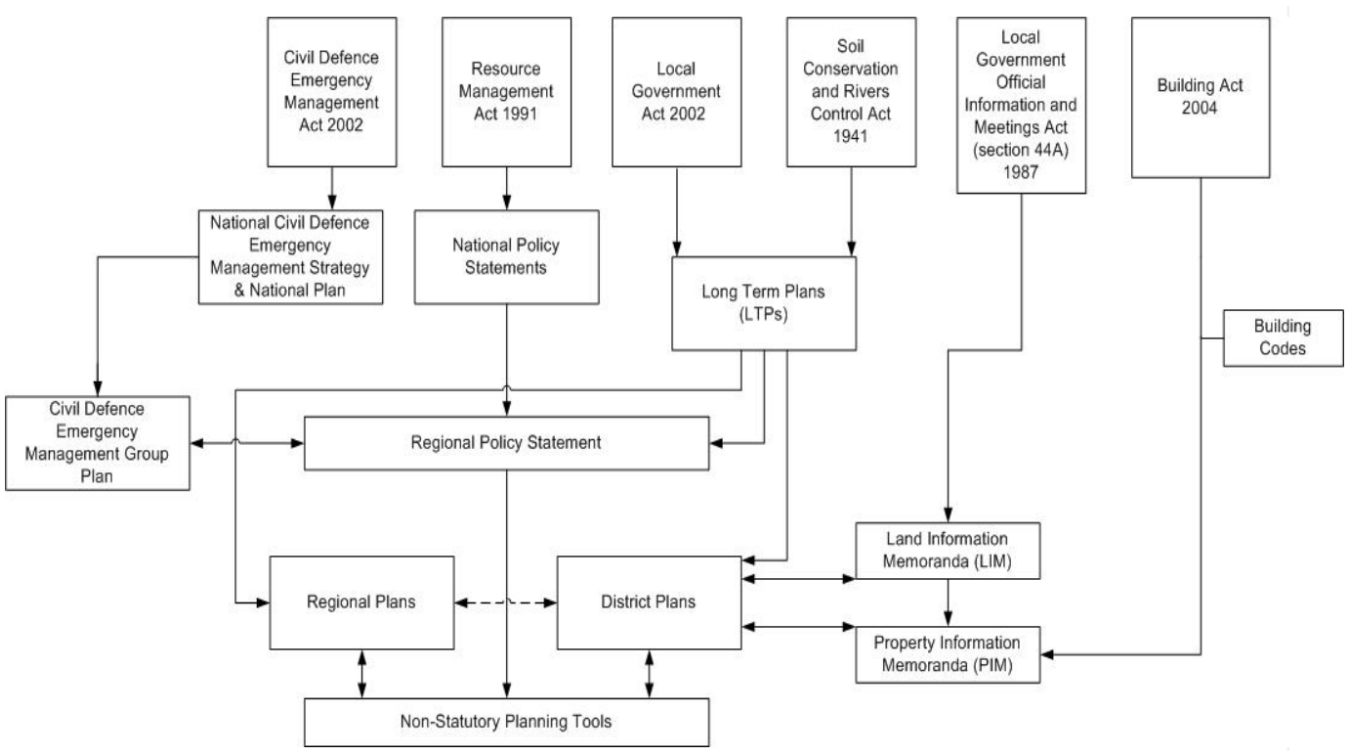

Figure 2. Relationships between legislation for the management of natural hazards (The Resource Management Act Quality Planning Resource, n.d.).

measures, which are commonly regarded as emergency management functions.

However, over time the growing recognition of risk reduction for natural hazard management has called for greater involvement of land use planning and building control (Beban & Saunders 2013; Glavovic et al., 2010; Saunders & Beban, 2012; Saunders et al., 2015; Saunders, Forsyth, Johnston, & Becker, 2007; Saunders et al., 2011). This is reflected through specific reference to tsunami risk management in Policy 25 of The New Zealand Coastal Policy Statement (Department of Conservation, 2010), and also with the recent amendments to Section 6 of the Resource Management Act (New Zealand Government, 1991), where the management of "significant risks" from natural hazards is now a matter of national importance.

Natural hazard risk modelling: RiskScape. One avenue for assessing and communicating natural hazard risk is through the use of risk modelling. Quantitative risk modelling combines deterministic or probabilistic hazard models with data detailing the type and location of assets that are exposed to the hazard, along with models that assess the vulnerability of that asset to the hazard. The result is an assessment of consequence, most often depicted as economic loss, but that can also be depicted through infrastructure or societal impacts dependent on the risk management objectives. Risk modelling then acts as an assessment and communication tool that presents the risk information in a way that assists decision makers and communities to better understand their risk and make more informed risk management decisions (Global Facility for Disaster Reduction and Recovery, 2014a; Global Facility for Disaster Reduction and Recovery, 2014b; Global Facility for Disaster Reduction and Recovery, 2014c; Pondard & Daly, 2011).

The risk modelling software used in this research is *RiskScape*[1]. RiskScape has been developed through scientific collaboration between NIWA and GNS Science[2] to meet the demand for a natural hazard impact and loss modelling tool for New Zealand conditions (King & Bell, 2009). RiskScape allows its users to assess tsunami-related risk through existing scenarios saved within the application, or to upload their own hazard scenario. Users then apply the hazard scenario to an asset database dependent on the asset for which they are assessing risk. The RiskScape asset database holds data on buildings but also includes data for electricity cables, roads, and reticulated water services. The hazard and asset data are then combined with a fragility function which calculates the probability or severity of damage for the asset given the intensity of the specific hazard. The output is an estimated loss or consequence as illustrated in Figure 3.

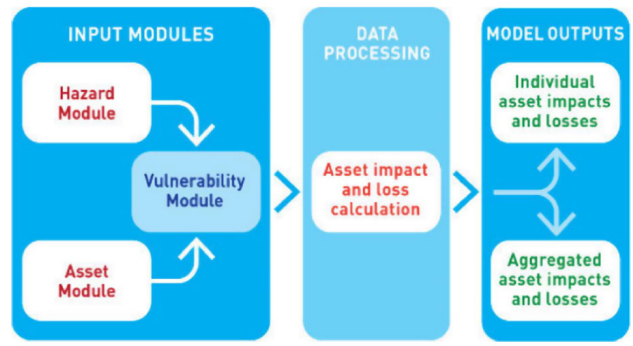

Figure 3. RiskScape modelling framework for how natural hazard and asset modules are combined with a vulnerability module to produce quantitative risk information. From Crawford, Crowley, et al. (2018).

The results from RiskScape modelling are presented in spreadsheet or map form, as shown in Figure 4, and can be aggregated. The results can also be exported into geographic information system (GIS) applications for further application and integration with other risk assessment and decision-making or planning tools.

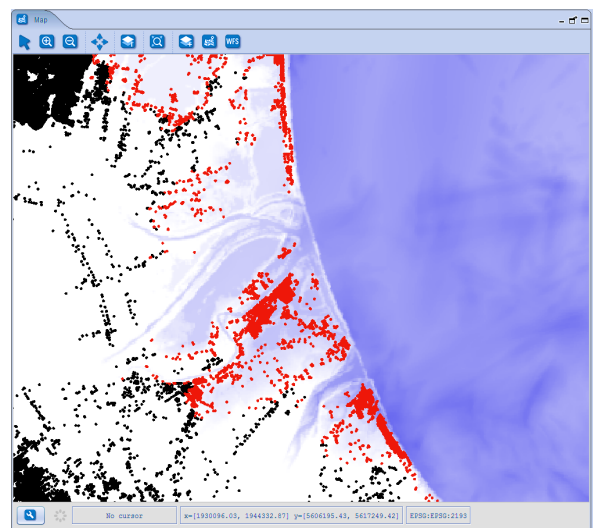

Figure 4. RiskScape modelling results shown in map form. The map shows a scenario of individual building exposure to tsunami inundation in Napier City following a M 8.9 earthquake generated in the Hikurangi Subduction Interface. The blue colours (located amongst the dots) represent the extent of tsunami inundation, the red dots represent buildings that have been impacted by tsunami inundation, and the black dots represent buildings that have not been impacted. (R. Paulik, personal communication, June 06, 2018).

1 https://www.riskscape.org.nz/

2 The National Institute of Water and Atmosphere (NIWA) and the Institute of Geological and Nuclear Science (GNS Science) are New Zealand Crown Research Institutes charged with promoting the transfer and dissemination of research, science, and technology.

Methods

Risk perception is subjective, involving people's feelings, beliefs, attitudes, and judgements about the harm and loss associated with the consequences of an event (Aven et al., 2011; Barnes, 2001; Mileti & O'Brien, 1992; Slovic, 1987). However, it is also framed by culture and society (Doyle, McClure, Paton, & Johnston, 2014), with our risk perception contextualised and informed by local values and norms and dependent on disciplinary frameworks (World Social Science Fellows on Risk Interpretation and Action, 2014). As such, this research is based on a social constructionist epistemology, where our meaning of reality is informed by creating models of the social world and sharing these models through communication (Young & Collin, 2004). The research follows a qualitative methodology, used because it examines the "why" and "how" of decision making, seeking to understand the depth and variety of people's feelings and perspectives, rather than quantities and distributions as studied through a quantitative methodology (Creswell, 2007).

Two methods were used in this research. Document analysis was used to gain an overview of the extent of tsunami risk-based policy, which was then corroborated with qualitative interviews. Qualitative interviews were used to gain a better understanding of subjective views towards tsunami risk management policy and of risk modelling as a communication tool. Each method is described in the following sections.

Document Analysis

Document analysis is a systematic procedure for reviewing or evaluating documents. When used qualitatively, this method requires data be examined and interpreted in order to elicit meaning, gain understanding, and develop empirical knowledge (Bowen, 2009). Document analysis has been used in this research to gain an overview of the distributions or patterns of local government tsunami risk management policy to corroborate the findings from the qualitative interviews. It does not seek to analyse the strength or significance of the policy.

New Zealand national legislation, local strategy, and planning policy documents were analysed for their provisions relating to natural hazards, risk management, and tsunami. Documents selected were required to be operational at the time of analysis and refer to natural hazard risk management within the Wellington, Hawke's Bay, or Gisborne regions. It is recognised that national tsunami warning arrangements are relatively well advanced, but wider risk management documentation is either still needed or in development.

Fifty-eight national and local policy documents were identified via a combination of internet searches and documents provided by participants. Examples include The New Zealand Coastal Policy Statement (Department of Conservation, 2010), The Hawke's Bay Regional Council - Long Term Plan 2012 – 2022 (Hawke's Bay Regional Council, 2012), and the City of Lower Hutt District Plan (Hutt City, 2016). A full list of the documents is given in the Appendix.

The documents were analysed using deductive analysis in accordance with predetermined criteria (Stemler, 2001). Previous analyses of New Zealand local government natural hazard policy were considered in determining criteria (Becker & Johnston, 2000; Glavovic et al, 2010; Kilvington & Saunders, 2016; Lawrence & Haasnoot, 2017; Saunders & Beban, 2012), with the criteria for this study primarily based on Saunders et al.'s (2015) evaluation of the use of land use and emergency management policy documents for natural hazards in New Zealand local government. In their study, a plan was considered to be best practice based on eight indicators including hazard identification, the inclusion of hazard specific rules, and the use of risk management language (e.g., consequence and likelihood). This study adapted Saunders et al's. (2015) best practice indicators to explore four objectives: the distribution pattern for natural hazards policies in general, the distribution pattern for tsunami policies specifically, the distribution pattern for risk-based policies in general, and the distribution pattern for tsunami risk-based policies specifically. Table 3 sets out these four objectives along with the predetermined criteria which inform each of them.

Limitations for this method are that relevant policy documents or references within the documents may have been missed from the analysis. Considering 58 documents were analysed covering central government legislation and local government strategy and planning policy, we are confident that our data reached the point of saturation (Patton, 2015), and that any missed documents or references would not have significantly altered the patterns identified from the analysis.

Qualitative Interviews

Exchange of dialogue, fluidly structured, and covering certain issues are common features of the qualitative

Table 3.
Document analysis criteria with objectives.

Criteria	Objectives
The document analysed:	
• has a section on natural hazards • has a definition for natural hazard • includes natural hazard policies	Explores patterns generally associated with natural hazard management policies.
• lists tsunami as a natural hazard • refers to tsunami as potentially affecting that district/region • includes tsunami policies • refers to tsunami inundation maps	Explores patterns specifically focussing on tsunami hazard management policies.
• has a definition of risk • sets out a risk based management model • includes risk based policies • links to risk management policies in other documents	Explores patterns generally associated with risk based policies.
• refers to tsunami risk – e.g. likelihood and consequences of certain magnitude events • includes tsunami risk based policies	Explores patterns specifically focussing on tsunami risk based policies.

interview, where meanings and understandings are co-produced through interaction (Edwards & Holland, 2013). Interview participants were identified and invited by a *gatekeeper* within each region who was able to transfer external information to colleagues within their organisation (Macdonald & Williams, 1993). The gatekeepers were all council staff who worked with the participants of this research. The gatekeepers were known to the lead author of this article, who had worked with them in previous, related research (Crawford, Crowley, et al., 2018; Crawford, Saunders, Doyle, & Johnston, 2018).

Twenty-three participants were interviewed across the Gisborne, Hawke's Bay, and Wellington regions, whose roles included the following functions:

- policy making;
- environmental science;
- land use planning;
- building control;
- emergency management;
- asset management;
- engineering; and
- hazard modelling.

The qualitative interview guide used in the interviews is presented below. The guide provides a semi-structured approach to the interview, to ensure that the same general areas of information are collected from each interviewee. "This provides more focus than the conversational approach, but still allows a degree of freedom and adaptability in getting information from the interviewee" (McNamara, 2009).

Objective 1: Encourage participants to express their thoughts, feelings and experiences on natural hazard risk management policy in NZ local government, especially what they think are the barriers for its development, and what the enablers are. Start by asking how natural hazard policy works in that Council. Capture discussion on:

- Its level of importance;
- How often policy is developed;
- How policy is applied;
- The local governance environment/mandate for policy development;
- RMA amendments to include risk focus;
- Risk based policy;
- Tsunami risk management; and
- Links across council for tsunami risk management.

Objective 2: Review participants' views on the use of risk modelling software (RiskScape), compared to without the use of risk modelling. Try to elicit thoughts and feelings on whether they think risk modelling can better communicate tsunami risk to influence decision maker perceptions, and willingness to engage in improved policy and procedure. Capture discussion on:

- Whether risk modelling changes the way participants perceive this risk;
- Whether risk modelling better communicates the risk, why and why not;
- Whether participants think risk modelling is better at creating motivation for developing more risk informed policy and procedure;
- What participants think are the barriers for the communication, perception, and motivation for this risk; and
- What participants think are the enablers for the communication, perception, and motivation for this risk.

Each interview lasted between one and one and a half hours with data captured through recordings which were transcribed and thematically analysed; thematic analysis "provides a flexible and useful research tool, which can potentially provide a rich and detailed, yet complex account of data" (Braun & Clarke, 2006. p.5). Themes were identified using an inductive *bottom-up*

approach, where the themes emerge from the data itself (Patton, 2015). The NVivo software package (Bazeley & Jackson, 2013) was used to assist with the analysis, categorisation, and organisation of the data into main themes with contributing subthemes.

Limitations for this method are that participants may feel uncomfortable revealing certain information, or the interviews may not capture the intended data. These were respectively managed via participants being assured that all data collected was anonymous and pooled across locations in the study area, and through the guidance of the qualitative interview guide to capture the intended data.

It is important to acknowledge the lead author's own positionality, having worked in risk and local government emergency management, and how this background has influenced his interpretation of the interview data (Landström et al., 2011; Whitman, Pain, & Milledge, 2015). When conducting the interviews, the lead author automatically adopted the position of *participant as observer* (Bryman, 2008) where he interacted with the participants and expressed his own views from experiences working in local government natural hazard risk management, while participants were also aware of his status as a researcher.

Results

The results section is separated into two parts reflecting the two different research methods used. The first section gives results for the policy document analysis, highlighting a paucity in local government risk-based tsunami policy. The second section (including its subsections) gives results from the qualitative interview analysis, identifying three emergent themes: "Disassociation and inability to internalise tsunami risk", "Reduced motivation for developing destructive tsunami policy", and "Risk modelling is valued but challenging".

Document Analysis

Fifty-eight central and local government policy documents across the Wellington, Hawke's Bay, and Gisborne regions were analysed for their policies relating to natural hazard, tsunami, and tsunami risk management. Our findings have been grouped in accordance with the four objectives of the document analysis as presented in Table 3: natural hazard policy distribution, tsunami policy distribution, risk based policy distribution, and tsunami risk-based policy distribution. Table 4 presents an overview of the distribution of natural hazard policy and risk-based policy across the documents, both in general and specifically.

Table 4.
Distribution for natural hazard, tsunami, and risk-based policy across central and local government policy documents.

Objectives & Criteria		Central Government (13 documents reviewed)	Local Government: Regional / Unitary Council (17 documents reviewed)	Local Government: District Council (28 documents reviewed)
Natural hazard management policies	Has a section on natural hazards	1	12	2
	Has a definition for natural hazard	5	10	5
	Includes natural hazard policies	9	13	14
Tsunami hazard management policies	Lists tsunami as a natural hazard	5	14	16
	Refers to tsunami as potentially affecting that district/region	0	15	17
	Includes tsunami policies	2	5	2
	Refers to tsunami inundation maps	0	2	0
Risk-based policies	Has a definition of risk	2	6	1
	Sets out a risk based management model	2	8	4
	Includes risk based policies	9	12	17
	Links to risk management policies in other documents	3	3	2
Tsunami risk-based policies	Refers to likelihood and consequence for certain magnitude tsunami events	0	1	0
	Includes tsunami risk based policies	1	1	1

Table 4 shows that natural hazard management is important for local government. This was stated by participants in the interviews and is reflected by the wide distribution of policy referring to general natural hazard management across long-term strategic plans, environmental policy statements, resource management plans, emergency management plans, and plans with specific focus areas such as coastal hazard management. The majority of resource management and emergency management plans for regional councils contain natural hazard-focussed sections, where long-term strategic plans tend not to specifically focus on natural hazards but refer to their general management throughout the document. While the documents contain policy specific to certain natural hazards, the majority of policies within and across the different document types take an *all-hazards* approach, where policies are designed to manage a generic range of hazards. Of the specific hazard policies, the majority focus on more frequent, experienced, and escalating hazards such as flooding, erosion, and sea level rise. These findings are similar to those presented by Saunders et al. (2015).

At the central government legislative level, tsunami is listed as a hazard or emergency in the Resource Management Act (New Zealand Government, 1991), the Civil Defence Emergency Management Act (New Zealand Government, 2002a), the Local Government Act (New Zealand Government, 2002b), the New Zealand Coastal Policy Statement (Department of Conservation, 2010), and the National Tsunami Advisory and Warning Supporting Plan (Ministry of Civil Defence and Emergency Management, 2017). Interestingly, and somewhat problematically, is how tsunami is not listed as a natural hazard within the Building Act (New Zealand Government, 2004), which instead refers to the less specific description of *inundation*. At the local government level, tsunami is recognised as a hazard across the majority of the policy documents analysed. While many of the documents state that tsunami could significantly impact their region, many rate other hazards such as earthquake or flooding as posing a greater risk. Of the 45 local government policy documents analysed, only seven documents contain policy addressing tsunami management. Of those seven documents, the majority of policy is general, for example “contingency plans shall be implemented for emergency events such as… tsunami” (Wairoa District Council, 2015, p. 48).

The only central government documents that define risk are the Civil Defence Emergency Management Act (New Zealand Government, 2002a) and the National Civil Defence Emergency Management Strategy (Department of Internal Affairs, 2008), defining it as the likelihood and consequences of a hazard. This scarcity of risk definition is reflected in local government documents, with only a few defining natural hazard risk as a combination of likelihood and consequence of a certain magnitude hazard. Of these documents, the majority are emergency management plans and coastal hazard strategies. When referring to risk, most local government policy documents are high-level and all-hazard, calling for the identification, assessment, communication, avoidance, and reduction of risks in general. While the documents contain policy requiring the management of risks, there is a paucity of policy setting out frameworks for how this is achieved. Of the documents that do contain risk management frameworks, the majority focus on frameworks for asset management, followed by water quality, hazardous substances, and contaminated site management. Only three of these documents refer to natural hazard risk management; these are contained in either emergency management or coastal hazard management plans.

Of the 58 national and local policy documents that were analysed, three contain specific tsunami risk-based policy. The New Zealand Coastal Policy Statement (Department of Conservation, 2010) does so at the central government level, with The Tairawhiti Civil Defence Emergency Management Group Plan 2016 – 2021 (Gisborne District Council, 2016) at the regional council level (as a unitary authority[3]) and The City of Lower Hutt District Plan (Hutt City, 2016) at the district council level. Whilst some further documents contain risk-based policies specific to coastal hazards, they are generic and do not specifically relate to tsunami risk management.

Qualitative Interview Analysis

Disassociation and inability to internalise tsunami risk. Interview participants commonly used return periods to describe tsunami likelihood, ranging from 500 to 3000 years. They stated that these numbers were unrealistic, or not something they would probably see in their lifetime. In general, participants conveyed that the likelihood of destructive tsunami was so remote that its risk was hard to understand:

> It’s not been in my lifetime, why would I worry about it? Therefore, when you start getting shown maps it’s

3 A unitary authority is a territorial authority that has the responsibilities, duties, and powers of a regional council.

like the whole area's new and it's like...It's not real. (Participant).

While participants logically understood that a destructive tsunami could impact at any time and that the consequences would be severe, they had difficulty internalising what the consequences would mean for them. Instead, participants chose to disassociate themselves from the risk, preferring to assure themselves that a destructive tsunami was very rare and that a tsunami "won't happen here":

I think ever since the Indonesian event in 2004, and then that big follow up by what happened in Japan in 2011, there's a real fear and perception out there that if we get a decent tsunami it's going to create devastation, huge devastation, but at the same time there is this, just this general thing "oh well but what is the chance of that happening, it won't happen here" sort of thing. (Participant).

Common across participant discussions was how important the coastal area was for their community to use and enjoy. Many participants lived in coastal areas and stated that, despite awareness of tsunami risk, living on the coast was preferable to living outside of a tsunami inundation area:

I live at Westshore, a big tsunami zone and I'm not going to move. I like living on the coast. It's worth my while, I think, to have that enjoyment as a trade-off for the risk that I think about. (Participant).

As such, even though the consequences of destructive tsunami are severe, participants stated that the "un-realness" of the likelihood and consequences in combination with people's affinity for living on the coast meant that they are prepared to accept the risk, believing that destructive tsunami will not happen to them:

People are willing to take a bit more risk around those areas and just accept the fact that there is tsunami, or these one-off major events, which have a return period of I think, two and a half thousand years, which is the largest modelled one. So most people go "well two and a half thousand years, I'll take my chances". (Participant).

Reduced motivation for developing destructive tsunami policy. Participants stated that currently there was not the same degree of focus within policy frameworks to cover the extremely rare events such as destructive tsunami, which are spaced out over hundreds or thousands of years. In-line with this short-term policy focus, participants found it easier to talk about risk management measures in place for more frequent, experienced hazards such as noise pollution, flooding, and erosion. Participants conveyed that these hazards were more pertinent issues that policy makers, decision makers, and the community could see every day, happening in front of their eyes. As such, policy for managing these more frequent hazards was well understood and received greater acceptance within the community. Participants stated that while tsunami was a coastal hazard, it was easier to separate tsunami from coastal hazard policy development and deal with more immediate concerns:

It's pretty easy to deal with some short-term stuff, you know, don't build on that hillside because it's in a slip zone, but tsunami is… you know… you're talking about hundreds and hundreds of years, so how do you identify what the risk is, how do you identify the policy response? (Participant).

Participants also stated that the cost of implementing tsunami risk management policy would outweigh its benefits, especially when viewed in conjunction with shorter-term planning timeframes for natural hazard management. They believed that while highly concentrated populations, such as Japan, may have the means to reduce tsunami risk by relocating their built assets or through building large protective structures, New Zealand did not have the population concentration or economic means to make that option realistic. Furthermore, participants referred to where tsunami protection walls were overtopped in the Great East Japan earthquake and tsunami of 2011, stating that even if there were means to build protective structures, this did not guarantee community protection. They thought that considering the "extremely unlikely" event of a large, destructive tsunami, they would deal with the consequences if they occurred, rather than pay for protective structures which could fail anyway.

Similar to their views on the cost-benefit of applying policy for tsunami protection, participants stated that a precautionary policy approach for destructive tsunami risk management would effectively prohibit community development and economic benefit. Given that community and economic development is central to the objectives of local government (New Zealand Government, 2002b), prohibiting development to manage tsunami risk "just doesn't stack up". This is especially relevant given that the major cities in the Gisborne, Hawke's Bay, and Wellington regions are

already located within tsunami inundation areas. Participants stated that policy which limited development of existing buildings in tsunami inundation areas was an issue that would potentially affect too much land and too many assets (built and human). Given the low-likelihood of destructive tsunami, participants were uncertain as to how policy could be developed where the benefit from applying the policy would be greater than the cost. Participants stated that there were more options for applying policies to manage development in *greenfield* areas where no existing building had taken place; however, they doubted whether policies that restricted greenfield development could be applied without property developer, community, and jurisdictive resistance:

> The uncertainty of tsunami risk sits in the really hard basket when you're looking at established development areas, obviously when you're planning new ones you can take those things into account, but if you're looking at managing existing areas it's really difficult. (Participant).

> It just doesn't stack up and I doubt whether we will, as an organisation, head to the Environment Court[4] to try and fight for those provisions and I don't think the Environment Court would be very receptive. (Participant).

Because of the low-likelihood of destructive tsunami and the uncertainties that they entail, policy development to manage tsunami risk is perceived as being in the "too hard basket". As such, planning and policy initiatives to reduce tsunami risk are less explored. One option for better communicating low-likelihood, destructive tsunami risk is through the use of risk modelling. However, as pointed out in the following section, risk modelling comes with its own challenges when applied within local government.

Risk modelling is valued but challenging. While some participants were not as familiar with the use of tsunami risk modelling as others, they all agreed that risk modelling was beneficial, especially as it can produce a visual representation of the risk with which people can more easily identify. Some participants referred to the colloquialism that "a picture is worth a thousand words". They added that the ability of risk modelling to spatially distribute natural hazard risks on maps made it a valuable communication tool for community awareness campaigns, for media use, and for increasing decision makers' risk awareness.

Participants also valued the ability of risk modelling to provide loss estimates for planning purposes. They stated that the ability of modelling to tabulate comparisons of loss, depending on differences in exposure and vulnerability of assets, made it useful for *Section 32* analyses (New Zealand Government, 1991), where benefits and costs, and considerations of alternatives, are required to be considered for the development of policies. They also referred to the value of risk modelling for emergency management, where modelled estimates of consequences can be used to inform readiness arrangements and pre-event recovery planning.

Almost all participants believed, especially in the case of low-likelihood hazards such as destructive tsunami, that modelled outputs which clearly and succinctly set out aggregated economic and infrastructural losses were beneficial for communicating risk and influencing decision makers' risk perceptions. However, participants expressed uncertainty as to whether risk modelling would actually change how decision makers would act. Some participants told of previous experiences where decision makers had rejected risk modelling outputs. These participants stated that officially, decision makers did not want to act because they were unsure of the quality of the modelled results; whereas unofficially, decision makers may not have wanted to act on the modelled results because of political reasons:

> I don't think anyone politically wants to say "yeah, the legacy I left in my tenure was to make sure that there were protection and policies in place to hamper the growth of a city because it exists in a tsunami zone..." (Participant).

In line with this, participants held reservations over the assumptions and uncertainties inherent within risk modelling. They expressed that risk modelling needed more transparency, rather than being a "black box", so that users could see how data was manipulated within the model and have more confidence in what it was telling them. They expressed that the assumptions of the models and lack of transparency were the first things that get contested by decision makers and the judicial system (e.g., Environment Court) when risk modelling had been used in the past to defend policy proposals.

4 The Environment Court of New Zealand works to solve issues relating to the Resource Management Act 1991. The court largely deals with appeals about the contents of regional and district plans and appeals arising out of applications for resource consents.

Further concerns that participants had regarding risk modelling was that input data, in a usable format and quality, was very scarce, that data generation was very costly, and that their councils did not have the spare capacity or capability to support in-house risk modelling. Consequently, risk modelling had not yet been able to provide the specific level of information needed to inform detailed land use and urban planning:

> The thing with planning is that it requires pretty detailed information in order to justify putting in those policy constraints at the end of the day. You have to absolutely have it backed up 100 percent because you will be fighting it through councils, politicians themselves are not going to approve something unless it's fully sound. (Participant).

As such, while participants saw risk modelling as beneficial, they were clear to state that it could only ever be a support tool for decision-making. Many referred to risk modelling as a communication tool, capable of conveying information in a way that influences risk awareness and perception, to help start decision maker discussions for policy development:

> That's probably a nice turn of phrase "as a communication tool" because I'm a firm believer that any model is there to support decision making not to make decisions. Only humans can do that in full judgement of the information available. So as a communications tool risk modelling is still quite valid. (Participant).

Discussion

> [Natural hazard preparedness] involves understanding how people construe the relationship between themselves, the hazard and the protective measures available to them and assisting their protective decision making within this socio-ecological context. (McIvor, Paton, & Johnston, 2017. p.45)

The results from the policy document analysis show that while natural hazard management is important for local government, there is a paucity of risk-based policy for tsunami management. Factors contributing to this are that the majority of policy takes a generic all-hazards approach, that existing policy tends to focus on more frequent, experienced, and escalating hazards, that the majority of tsunami-specific policy is unclear and non-prescriptive, and that risk-based policy is high-level and lacks reference to frameworks for how risk management would be achieved. As such, of the 58 national and local policy documents that were analysed, only three contain specific tsunami risk-based policy.

This paucity of tsunami risk management policy reinforces similar findings on the need for more specific hazard policy in New Zealand local government (Becker & Johnston, 2000; Glavovic et al, 2010; Local Government New Zealand, 2014; Saunders et al., 2014). The tendency to refrain from developing hazard-specific risk policy in favour of an all-hazards approach could be attributed to policy makers trying not to miss hazards out, as well as resource issues pushing them to achieve the greatest policy coverage with limited budgets. However, given the qualitative interview results where participants logically understand tsunami risk but choose to disassociate from it, we propose that the paucity in specific risk-based tsunami policy could also be attributed to cognitive biases.

Cognitive biases are a human condition where heuristics can sometimes cause us to behave in contrary or seemingly illogical ways. Over 100 cognitive biases have been recognised (Ehrlinger, Readinger, & Kim, 2016), with many acting in contradictory ways to others. While the following discussion focusses on how cognitive biases can influence people to under-perceive risk, other types of cognitive bias can influence people to over-perceive risk (Notebaert, Clarke, & MacLeod, 2016).

While the results show that participants logically understand that an unlikely, destructive tsunami can occur at any time and that the consequences will be severe, their difficulty in internalising the consequences from such an event shows a disassociation from the risk: that "tsunami won't happen to us". Research has established a number of reasons for this. People tend to have a poor understanding of low likelihoods (Doyle & Potter, 2015; Shoemaker 1980; Slovic, Fischoff, & Lichtenstein, 1982). Slovic et al. (1982) found that people are insensitive to differences in very low probabilities and that below a certain threshold, low probabilities are perceived as the same and tend to zero. Shoemaker (1980) stated that people either ignore low probabilities or are unable to make rational decisions involving low probabilities. Henrich, McClure, and Crozier (2015) reported that people have difficulty perceiving low-likelihood disaster risk especially when it is framed as a recurrence interval (e.g., 1/ 1000 years). McClure, Allen, and Walkey (2001), Khan, Crozier, and Kennedy (2012), and Baytiyeh and Naja (2016) stated that people are less likely to prepare for disasters due the belief that disasters are too destructive to prepare

for successfully. Fraser et al. (2016), Mileti and O'Brien (1992), and Solberg, Rossetto, and Joffe (2010) referred to how warning fatigue and normalisation bias can drive people to underestimate the risk of natural hazards.

Cognitive biases which can influence practitioners to disassociate themselves from tsunami risk include:

- The Ostrich Effect: a tendency to disbelieve or ignore something that has a negative emotional effect, even if there is evidence to the contrary;
- The Optimism Bias: a tendency to underestimate the likelihood that negative consequences will occur from future threats;
- The Confirmation Bias: a tendency to search for, interpret, favour, and recall information in a way that confirms one's own pre-existing beliefs or hypothesis; and
- The Amnesia Bias: a tendency to forget too quickly the lessons of past disasters.

The results show that because of the low likelihood of destructive tsunami and the uncertainties they entail, practitioners perceive that developing policy to manage tsunami risk sits in the "too hard basket", which results in a paucity of tsunami risk management policy. Cognitive biases which can influence practitioners' motivations towards developing policy include:

- The Myopia Bias: a tendency to focus on overly short future time horizons when appraising costs and the potential benefits of protective investments;
- The Availability Heuristic: a tendency to act on threats which have previously been experienced, or are easy to imagine;
- The Inertia Bias: a tendency to maintain the status quo or adopt a default option when there is uncertainty about the potential benefits of investing in alternative protective measures; and
- The Bandwagon Effect or Groupthink: a tendency for people to do something primarily because other people are doing it, regardless of their own beliefs, which they may ignore or override.

The types of cognitive biases that influence policy development for low-likelihood, destructive tsunami are difficult to overcome. This is because these biases tend to be resistant to logic, deconstruction, or the use of training tools (Montibeller & von Winterfeldt, 2015; Weinstein & Klein, 1995). *Debiasing* measures that can improve decision maker risk perceptions include (Montibeller & von Winterfeldt 2015; Parkhurst, 2017; United States Government, 2009):

- Clear, easily digestible communication of the risk;
- Identification of the consequences associated with the risk;
- Provision of alternative scenarios and counterexamples; and
- Use of diverse expert information.

We propose that risk modelling can reduce the impact of these types of cognitive bias and therefore support the development of tsunami risk-based policy. The model used in the interviews (RiskScape) visually presents information in map form, which participants found easy to understand and with which to identify. The framework for the RiskScape model has been developed using robust science (Schmidt et al., 2011), is populated with diverse expert information for hazard and fragility models (Bell, Paulik, & Wadwha, 2015; Cousins, 2015; Kwok, 2016; Uma, 2009), and is capable of presenting modelled consequences in map form and as numerical tables.

The results highlight how participants thought "a picture is worth a thousand words", implying that the risk model visually communicated risk in a way that they found more informative and easily digestible than other traditional methods. Furthermore, even though they had not personally experienced the low-likelihood tsunami scenario depicted in the risk model, they stated that after seeing the results, they were better inclined to act on the information presented. Participants also thought that the aggregated economic and infrastructural consequences presented in the numerical tables was beneficial for influencing decision makers' risk perceptions. As such, participants agreed that the ability of RiskScape to communicate consequences visually and numerically could help reduce misperceptions associated with a tendency to forget the lessons from similar disasters or underinvest in risk reduction measures. Participants also valued the ability of RiskScape to provide alternative scenarios. While this enables them to perform cost-benefit analyses for different risk reduction measures, it also provides more certainty around investing in those measures, thus enabling decision makers to move past biases associated with maintaining the status quo.

However, even though participants see risk modelling as beneficial for communicating past cognitive biases and risk perceptions for low-likelihood tsunami, this has not yet been achieved. Concerns relating to data availability, quality and cost, the capacity and capability to use risk models, and trust in modelled results mean that modelling is not widely used in New Zealand local government (Crawford, Saunders et al., 2018). Also

of concern are participants' views that while decision makers may correctly perceive the risks communicated through risk modelling, they may not act upon them for political reasons.

Recommendations

This research reveals a number of challenges for low-likelihood, destructive tsunami risk management:

- A paucity of tsunami risk based policy;
- Cognitive biases influencing tsunami risk perception;
- Challenges for how easily risk modelling can be used within local government; and
- Concerns about decision maker motivation to enable tsunami risk management policy development.

As such, we recommend the following solutions to further develop a pathway forward for how local government could better match tsunami risk management policy with low-likelihood, destructive tsunami risk:

1) Further resource national risk management initiatives, for example the Local Government Risk Agency[5], to better enable the development and application of natural hazard risk management frameworks within local government. This could be achieved through structured collaboration and training across the different local government functions responsible for natural hazard risk management (Crawford, Saunders et al., 2018; Saunders et al., 2014). One option is regular risk management workshops to assess risks and what can be done to reduce them. The result is a shared understanding of each other's risk management roles (Doyle & Paton, 2018), greater integration across functions, and an improved ability to develop specific risk-based policy for destructive tsunami, rather than an all-hazard policy approach.
2) Include debiasing techniques as part of natural hazard risk management workshops so that practitioners and decision makers are better informed about how innate cognitive biases influence their perceptions that destructive tsunami "won't happen here". While increased awareness of cognitive biases may not change risk perceptions, it provides greater context when considering how acceptable the risk information is, allowing practitioners and decision makers to make more informed decisions.
3) Co-develop risk modelling through a bottom-up, participatory approach to enhance the usefulness and usability of the models (Newman et al., 2017). This approach would enable local government users to influence model development so that models can process a wider range of data formats (therefore increasing data availability), have a more intuitive user interface, and have increased quality of information output (Global Facility for Disaster Reduction and Recovery, 2014a; Global Facility for Disaster Reduction and Recovery, 2016). This would tie in with initiatives to increase local government understanding of risk management so that practitioners and decision makers have a better understanding of the capability and value of risk models and greater confidence in modelled information.
4) Review the flexibility of natural hazard policy instruments to enable policy for low-likelihood hazards that have intervals over thousands of years, thus providing a way forward for long, long-term planning instruments (Lawrence et al., 2015). These long, long-term planning instruments could operate outside of shorter-term planning cycles and apply policy across 100 – 500 years, incrementally reducing community exposure and vulnerability to natural hazards over generations. A long, long-term plan would separate low-likelihood, destructive tsunami risk management from the more immediate political, financial, and community development issues which currently influence decision makers to perceive it as sitting in the "too-hard-basket".

Furthermore, we propose that these challenges arise from more fundamental issues relating to how natural hazard risks are governed in New Zealand and other countries. When discussing this with practitioners in the interviews, they referred to:

- A complex natural hazard management legislative environment;
- Limited national-level clear, structured guidance;
- Lack of any mandate within local government to lead cross-council natural hazard management functions;
- Misperception or lack of integration across natural hazard management functions;
- The scarcity of available natural hazard data and information;
- A disconnect between science and policy;
- Mismatched policy and planning timeframes across land use planning, emergency management, building codes, and local government responsibilities;

5 Local Government New Zealand (LGNZ) has proposed a Local Government Risk Agency that pools and coordinates local government resources to lower the risk and cost of disaster. https://www.lgnz.co.nz/our-work/local-government-risk-agency/

- The differing requirements of decision makers across different practitioners' functions, politicians, and between practitioners and politicians; and
- A shortage of resources impacting on capacity and capability.

These issues are complex, interrelated, and entrenched within local government. Participants reported that these issues result in long timeframes for natural hazard policy development, a paucity in risk-based policy, and a reduced ability to apply natural hazard management solutions such as risk modelling (Crawford, Crowley et al., 2018). Considering this, we recommend the ongoing review of the interrelationship across natural hazard provisions in New Zealand to further explore governance approaches which can more effectively enable the application of natural hazard risk management solutions.

Conclusion

While the regions of Wellington, Hawke's Bay, and Gisborne are at risk of experiencing the most destructive tsunami that New Zealand is likely to encounter over a 1000-year timeframe, this risk is not currently matched by tsunami risk management policy. An analysis of 58 central and local government policy documents for those regions reveals only three that contain specific tsunami risk-based policy. We propose that this paucity in policy is influenced by cognitive biases which can cause people to disassociate themselves from low-likelihood tsunami risk and reduce motivation for developing risk-based policy. We argue that risk modelling (RiskScape) can help overcome these cognitive biases and aid policy development. While participants see value in risk modelling as a tool to communicate tsunami risk in a way that is more digestible and useful, they are uncertain of how easily it could be used and how acceptable its information is for decision makers. As such, we recommend participatory risk modelling to work in combination with risk management training, cognitive debiasing techniques, and long, long-term planning to overcome the challenge of low-likelihood tsunami risk perception. The complexity of New Zealand's natural hazard governance system remains an issue. However, with a deeper understanding of how New Zealand's natural hazard governance system impacts on the development and application of natural hazard policy, we can better apply solutions and enable our communities to become safer, sustainable, and more resilient.

Acknowledgements:

This research was made possible through funding from the New Zealand Earthquake Commission (EQC) and the Australian Bushfire Natural Hazards Cooperative Research Centre (BNHCRC). This research was also partially supported by QuakeCoRE, a New Zealand Tertiary Education Commission-funded Centre. This is QuakeCoRE publication number 0366.

The authors appreciate Ryan Paulik's contributions regarding RiskScape and the useful comments made by the reviewers. We would also like to thank the research participants from councils in the Gisborne, Hawke's Bay, and Wellington regions of New Zealand.

This research was undertaken with low-risk ethical clearance based on the Massey University Code of Ethical Conduct for Research obtained from the Massey University Research Ethics Office.

References

Aven, T., Renn, O., & Rosa, E. A. (2011). On the ontological status of the concept of risk. *Safety Science, 49*(8), 1074-1079. doi: 10.1016/j.ssci.2011.04.15

Barnes, P. (2001). Regulating safety in an unsafe world. *Journal of Hazardous Materials, 86*, 25-37.

Basher, R. (2016). High stakes: Disaster risk in New Zealand. *Policy Quarterly, 12*(3), 25-29. doi: 10.26686/pq.v12i3.4615

Baytiyeh, H., & Naja, M. (2016). The effects of fatalism and denial on earthquake preparedness levels. *Disaster Prevention and Management, 25*(2), 154-167. doi: 10.1108/DPM-07-2015-0168

Bazeley, P., & Jackson, K. (Eds.). (2013*). Qualitative data analysis with NVivo*. Thousand Oaks, CA, US: Sage Publications, Inc.

Becker, J. S., & Johnston, D. M. (2000). Planning and policy for earthquake hazards in New Zealand. *GNS Science Report 2000/28.* 34 p.

Bell, R.G., Paulik, R., & Wadwha, S. (2015). National and regional risk exposure in low lying coastal areas. *NIWA Client Report No. HAM2015-006.* 270 p.

Bowen, G. A. (2009). Document analysis as a qualitative research method. *Qualitative Research Journal, 9*(2), 27-40. doi: 10.3316/QRJ0902027

Braun, V., & Clarke, V. (2006) Using thematic analysis in psychology. *Qualitative Research in Psychology, 3*(2), 77-101. doi: 10.1191/1478088706qp063oa

Bryman, A. (2008). *Social research methods* (3rd ed.). Oxford, UK: Oxford University Press.

Cousins, W.J. (2015). Occupancy model for RiskScape. *GNS Science Report 2013/52.* 25 p.

Crawford, M. H., Crowley, K., Potter, S. H., Saunders, W. S. A., & Johnston, D. M. (2018). 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. doi: 10.1016/j.ijdrr.2018.01.011

Crawford, M. H., Saunders, W. S. A., Doyle, E. E., & Johnston, D. M. (2018). End-user perceptions and use of natural hazard risk modelling across policy making, land use planning, and emergency management within New Zealand local government. In K. Stock & D. Bunker (Eds.), *Proceedings of ISCRAM Asia Pacific 2018: Innovating for Resilience – 1st International Conference on Information Systems for Crisis Response and Management Asia Pacific*. (pp. 550–560). Wellington, NZ.

Creswell, J. W. (2007). *Qualitative inquiry and research design: Choosing among five approaches*. Thousand Oaks, CA, US: Sage Publications, Inc.

Department of Conservation. (2010). New Zealand Coastal Policy Statement. Retrieved from www.doc.govt.nz/about-us/science-publications/conservation-publications/marine-and-coastal/new-zealand-coastal-policy-statement/new-zealand-coastal-policy-statement-2010/

Department of Internal Affairs. (2008). National Civil Defence Emergency Management Strategy. Retrieved from www.civildefence.govt.nz/assets/Uploads/publications/national-CDEM-strategy-2008.pdf

Department of the Prime Minister and Cabinet. (2007). National Hazardscape Report. Retrieved from www.civildefence.govt.nz/assets/Uploads/publications/national-hazardscape-report-sept-2007-complete.pdf

Doyle, E. E., McClure, J., Paton, D., & Johnston, D. M. (2014). Uncertainty and decision making: Volcanic crisis scenarios. *International Journal of Disaster Risk Reduction, 10,* 75-101. doi: 10.1016/j.idrr.2104.07.006

Doyle, E. E. H., & Paton, D. (2018). Decision-making: Preventing miscommunication and creating shared meaning between stakeholders. In K. Nemeth (Ed.), *Advances in Volcanology* (pp. 549 - 570). Switzerland: Springer.

Doyle, E. E. H., & Potter, S. H. (2015). Methodology for the development of a probability translation table for GeoNet. *GNS Science Report 2015/67.* 18 p.

Edwards, R., & Holland, J. (2013). *What is qualitative interviewing?* London, UK: Bloomsbury Academic.

Ehrlinger, J., Readinger, W. O., & Kim, B. (2016). Decision-making and cognitive biases [PDF file]. Retrieved from https://pdfs.semanticscholar.org/0116/3233d7b3c9fe76faed386bed27bb364b652d.pdf

Fraser, S. A., Doyle, E. E. H., Wright, K. C., Potter, S. H., McClure, J., Johnston, D. M., ... & Johal, S. (2016). Tsunami response behaviour during and following two local-source earthquakes in Wellington, New Zealand. *International Journal of Disaster Risk Reduction, 16,* 123-133. doi: 10.1016/j.idrr.2016.02.008

Gill, D., Clough, P., & Webb. T. (2015). Tsunami risk facing New Zealand [PDF file]. Retrieved from www.eqc.govt.nz/sites/public_files/Report%20on%20Tsunami%20Risk%20facing%20New%20Zealand%20Aug%202015.pdf

Gisborne District Council. (2016). Tairawhiti Civil Defence Emergency Management Group Plan 2016 – 2021 [PDF file]. Retrieved from www.gdc.govt.nz/assets/Files/Civil-Defence/Group-Plan-2016-Part-A-Introduction-Risk-and-Hazards-Strategic-and-Management.pdf

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. *Natural Hazards, 54*, 679-706. doi: 10.1007/s11069-009-9494-9

Global Facility for Disaster Reduction and Recovery. (2014a). Understanding risk: Review of open source and open access software packages available to quantify risk from natural hazards. Retrieved from www.gfdrr.org/en/publication/understanding-risk-review-open-source-and-open-access-software-packages-available

Global Facility for Disaster Reduction and Recovery. (2014b). Understanding risk: The evolution of disaster risk assessment since 2005 [PDF file]. Retrieved from www.gfdrr.org/sites/default/files/publication/UR_Proceedings_120912_reduced.pdf

Global Facility for Disaster Reduction and Recovery. (2014c). Understanding risk in an evolving world: Emerging best practices in natural disaster risk assessment [PDF file]. Retrieved from www.gfdrr.org/sites/gfdrr/files/publication/Understanding_Risk-Web_Version-rev_1.8.0.pdf

Global Facility for Disaster Reduction and Recovery. (2016). Solving the puzzle: Innovating to reduce risk. Retrieved from www.gfdrr.org/en/solving-the-puzzle-report

Hawke's Bay Regional Council. (2012). Long Term Plan 2012 – 2022 [PDF file]. Retrieved from www.hbrc.govt.nz/assets/Document-Library/Plans/Annual-Plans-and-LT-Plans/Long-term-Plan-2012-2022/LTP-Full.pdf

Henrich, L., McClure, J., & Crozier, M. (2015). Effects of risk framing on earthquake risk perception: Life-time frequencies enhance recognition of the risk. *International Journal of Disaster Risk Reduction, 13*, 145-150. doi: 10.1016/i.jdrr.2015.05.003

Horspool, N., Cousins, W. J., & Power, W. L. (2015). Review of tsunami risk facing New Zealand: A 2015 update. *GNS Science Consultancy Report, 38.* 52 p.

Hutt City Council. (2016). City of Lower Hutt District Plan. Retrieved from www.huttcity.govt.nz/Your-Council/Plans-publications-and-bylaws/District-Plan/

International Organization for Standardization. (2009). ISO 31000: Risk management: Principles and guidelines. Sydney, Australia and Wellington, NZ: Standards Australia/Standards New Zealand.

Johnston, D., Pettersson, R., Downes, G., Paton, D., Leonard, G., Pishief, K., & Bell, R. (2008). Developing an effective tsunami warning system: Lessons from the 1960 Chile earthquake tsunami for New Zealand coastal communities. *Kotuitui: New Zealand Journal of Social Sciences Online, 3*(2), 105-120. doi: 10.1080/1177083X.2008.9522436

Johnston, D. M., Saunders, W. S. A., Leonard, G. S., Beban, J., Wright, K., & Fraser, S. A. (2014). History of tsunami planning in New Zealand: 1960 to the present. In M Gjerde & E. Petrovic (Eds.), *UHPH_14: Landscapes and ecologies of urban and planning history. Proceedings of the 12th conference of the Australasian Urban History/Planning History Group* (pp. 361-372). Wellington, NZ: Australasian Urban History/Planning History Group and Victoria University of Wellington.

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*(2), 501-529. doi: 10.1007/s11069-012-0091-y

Kilvington, M., & Saunders, W.S.A. (2016). The role of science in land use planning: Exploring the challenges and opportunities to improve practice. *GNS Science Report 2016/057.* 53 p.

King, A., & Bell, R. (2005). RiskScape New Zealand: A multihazard loss modelling tool [PDF file]. Retrieved from http://nzsee.org.nz/db/2006/Paper30.pdf

King, D. N. (2015). Tsunami hazard, assessment and risk in Aotearoa–New Zealand: A systematic review AD 1868–2012. *Earth-Science Reviews, 145,* 25-42. doi: 10.1016/j.earscirev.2015.02.004

King, A., & Bell, R. (2009). RiskScape Project: 2004 – 2008. *NIWA Science Report 2009/75*. 172p.

Kwok, A.H. (2016). Integrating social vulnerability indicators in RiskScape's earthquake risk modelling. *GNS Science Report 2016/09 iv.* 58 p.

Landström, C., Whatmore, S. J., Lane, S. N., Odoni, N. A., Ward, N., & Bradley, S. (2011). Coproducing flood risk knowledge: Redistributing expertise in critical 'participatory modelling'. *Environment and Planning A, 43*, 1617-1633. doi: 10.1068/a43482

Lawrence, J. (2018). Implications of climate change for New Zealand's natural hazards risk management. *Policy Quarterly, 12*(3), 1-10. doi: 10.26686/pq.v12i3.4605

Lawrence, J., & Haasnoot, M. (2017). What it took to catalyse uptake of dynamic adaptive pathways planning to address climate change uncertainty. *Environmental Science & Policy, 68*, 47-57. doi: 10.1016/j.envsci.2016.12.003

Lawrence, J., Sullivan, F., Lash, A., Ide, G., Cameron, C., & McGlinchey, L. (2015). Adapting to changing climate risk by local government in New Zealand: Institutional practice barriers and enablers. *Local Environment, 20*, 298-320. doi: 10.1080/13549839.2013.839643

Local Government New Zealand. (2014). Managing natural hazard risk in New Zealand – towards more resilient communities [PDF file]. Retrieved from www.lgnz.co.nz/assets/Publications/de504aaea2/Managing-natural-hazards-LGNZ-think-piece.pdf

Macdonald, S., & Williams, C. (1993). Beyond the boundary: An information perspective on the role of the gatekeeper in the organization. *Journal of Product Innovation Management, 10*, 417-427. doi: 10.1016/0737-6782(93)90099-C

McClure, J., Allen, M. W., & Walkey, F. (2001). Countering fatalism: Causal information in news reports affects judgments about earthquake damage. *Basic and Applied Social Psychology, 23*, 109-121. doi: 10.1207/S153424834BASP2302_3

McNamara, C. (2009). General guidelines for conducting interviews. Retrieved from https://managementhelp.org/businessresearch/interviews.htm

McIvor, D., Paton, D., & Johnston, D. (2017). Modelling community preparation for natural hazards: Understanding hazard cognitions. *Journal of Pacific Rim Psychology, 3*(2), 39-46. doi: 10.1375/prp.3.2.39

Meyer, R., & Kunreuther, H. (2017). *The ostrich paradox: Why we underprepare for disasters.* Philadelphia, PA, US: Wharton Digital Press.

Mileti, D. S., & O'Brien, P. W. (1992). Warnings during disaster: Normalizing communicated risk. *Social Problems, 39*, 40-57. doi: 10.2307/3096912

Ministry of Civil Defence and Emergency Management (2017). *Tsunami Advisory and Warning Plan: Supporting Plan SP 01/17.* Wellington, NZ: Ministry of Civil Defence and Emergency Management

Montibeller, G., & Von Winterfeldt, D. (2015). Cognitive and motivational biases in decision and risk analysis. *Risk Analysis, 35*, 1230-1251. doi: 10.1111/risa.12360

Newman, J. P., Maier, H. R., Riddell, G. A., Zecchin, A. C., Daniell, J. E., Schaefer, A. M., ... & Newland, C. P. (2017). Review of literature on decision support systems for natural hazard risk reduction: Current status and future research directions. *Environmental Modelling & Software, 96,* 378-409. doi: 10.1016/j.envsoft.2017.06.042

New Zealand Government. (1991). *Resource Management Act 1991.* Wellington, NZ: New Zealand Government.

New Zealand Government. (2002a). *Civil Defence Emergency Management Act.* Wellington, NZ: New Zealand Government.

New Zealand Government. (2002b). *Local Government Act.* Wellington, NZ: New Zealand Government.

New Zealand Government. (2004). *Building Act.* Wellington, NZ: New Zealand Government.

Notebaert, L., Clarke, P. J., & MacLeod, C. (2016). Does attentional bias to threat ameliorate or exacerbate the detrimental effect of trait anxiety on behavioural preparedness for real-world danger? *Australian Journal of Psychology*, *68*(3), 166-177. doi: 10.1111/ajpy.12133

Parkhurst, J. (2017). Mitigating evidentiary bias in planning and policy-making: Comment on "Reflective practice: How the World Bank explored its own biases?" *International Journal of Health Policy and Management, 6*, 103. doi: 10.15171/ijhpm.2016.96

Patton, M. (2015). *Qualitative research & evaluation methods: Integrating theory and practice* (4th ed.). Thousand Oaks, CA, US: Sage Publications, Inc.

Pondard, N., & Daly, M. (2011). Hazards risk modelling: An approach providing risk management solutions for local government. *GNS Miscellaneous Series 38.* 14 p.

Power, W. L. (2013). Review of tsunami hazard in New Zealand. *GNS Science Report 2013/131.* 222 p.

Power, W., Wallace, L., & Reyners, M. (2008). Tsunami hazard posed by earthquakes on the Hikurangi subduction zone interface. *GNS Science Report 2008/40.* 44 p.

Saunders, W., & Beban, J. G. (2012). Putting R (isk) in the RMA: Technical Advisory Group recommendations on the Resource Management Act 1991 and implications for natural hazards planning. *GNS Science Miscellaneous Series 48*. 51 p.

Saunders, W., Forsyth, J., Johnston, D., & Becker, J. (2007). Strengthening linkages between land-use planning and emergency management in New Zealand. *Australian Journal of Emergency Management, 22*, 36-43.

Saunders, W., Grace, E. S., & Beban, J. G. (2014). Overview of the state of land use planning for natural hazards in New Zealand. *GNS Science Report 2014/63.* 36 p.

Saunders, W., Grace, E., Beban, J., & Johnston, D. (2015). Evaluating land use and emergency management plans for natural hazards as a function of good governance: A case study from New Zealand. *International Journal of Disaster Risk Science, 6*, 62-74. doi: 10.1007/s13753-015-0039-4

Saunders, W., Prasetya, G., & Leonard, G.S. (2011). New Zealand's Next Top Model: Integrating tsunami inundation modelling into land use planning. *GNS Science Miscellaneous Series 34.* 42 p.

Schmidt, J., Matcham, I., Reese, S., King, A., Bell, R., Henderson, R., ... & Heron, D. (2011). Quantitative multi-risk analysis for natural hazards: A framework for multi-risk modelling. *Natural Hazards, 58*, 1169-1192. doi: 10.1007/s11069-011-9721-z

Shoemaker, P.J.H. (1980). *Experiments on decisions under risk: The expected utility hypothesis*. Boston, MA, US: Martinus Nijhoff Publishing.

Slovic, P. (1987). Perceptions of risk. *Science, 236*, 280-285. doi: 10.1126/science.3563507

Slovic, P., Fischhoff, B., & Lichtenstein, S. (1982). Facts versus fears: Understanding perceived risk. In D. Kahneman, P. Slovic, & A. Tversky (Eds.), *Judgment under uncertainty: Heuristic and biases* (pp. 463-490). Cambridge, UK: Cambridge University Press.

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*, 1663-1677. doi: 10.5194/nhess-10-1663-2010

Stemler, S. (2001). An overview of content analysis. *Practical Assessment, Research and Evaluation, 7*(17), 137-146.

The Resource Management Act Quality Planning Resource (n.d.). Introduction to natural hazards and the legislative framework for hazard management. Retrieved from www.qualityplanning.org.nz/index.php/planning-tools/natural-hazards/introduction-to-natural-hazards-and-the-legislative-framework-for-hazard-management

Uma, S.R. (2009). Rapid assessment of buildings with initial evaluation procedure for earthquakes. *GNS Science Report 2009/26*, 45 p.

United States Government. (2009). A Tradecraft primer: Structured analytical techniques for improving intelligence analysis. Retrieved from www.cia.gov/library/publications/publications-rss-updates/tradecraft-primer-may-4-2009.html

Wairoa District Council (2015). 2015-2025 Long Term Plan (LTP) [PDF file]. Retrieved from www.wairoadc.govt.nz/assets/Document-Library/Plans/Annual-Plans-and-Ten-Year-Plans/Long-Term-Plan-2015-25.pdf

Webb, T. (2005). Review of New Zealand's preparedness for tsunami hazard, comparison to risk and recommendations for treatment. *GNS Client Report 2005/162*. 119 p.

Weinstein, N. D., & Klein, W. M. (1995). Resistance of personal risk perceptions to debiasing interventions. *Health Psychology, 14*(2), 132-140. doi: 10.1037/0278-6133.14.2.132

Whitman, G. P., Pain, R., & Milledge, D. G. (2015). Going with the flow? Using participatory action research in physical geography. *Progress in Physical Geography, 39*, 622-639. doi: 10.1177/0309133315589707

World Social Science Fellows on Risk Interpretation and Action (2014). Reporting on the seminar – Risk Interpretation and Action (RIA): Decision making under conditions of uncertainty. *Australasian Journal of Disaster and Trauma Studies, 18*(1), 27-37.

Young, R. A., & Collin, A. (2004). Introduction: Constructivism and social constructionism in the career field. *Journal of Vocational Behavior, 64*, 373-388. doi: 10.1016/j.jvb.2003.12.005

Appendix

Natural hazard policy documents included in document analysis

1	Resource Management Act 1991
2	Building Act 2004
3	Civil Defence Emergency Management Act 2002
4	Local Government Act 2002
5	Environment Act 1986
6	Local Government Official Information and Meetings Act 1987
7	New Zealand Coastal Policy Statement 2010
8	National Civil Defence Emergency Management Plan Order 2015
9	Department of Internal Affairs (2008) National Civil Defence Emergency Management Strategy
10	Building Regulations 1992
11	MCDEM (2016) National Tsunami Advisory and Warning Supporting Plan [SP 01/16]
12	MCDEM (2015) CDEM Group Planning - Director's Guideline for Civil Defence Emergency Management Groups [DGL 09/15]
13	The Building Regulations 1992
14	Hawke's Bay Regional Council (2006) Hawke's Bay Regional Resource Management Plan including the Regional Policy Statement (RPS).
15	Hawke's Bay Emergency Management Group (2016) Group Plan 2014 – 2019.
16	Hawke's Bay Regional Council (2014) Hawke's Bay Regional Coastal Environment Plan.
17	Hawke's Bay Regional Council, Napier City Council, Hastings District Council (TBC) Clifton to Tangoio Coastal Hazards Strategy 2120
18	Hawke's Bay Regional Council (2011) Strategic Plan
19	Hawke's Bay Regional Council (2011) Long Term Plan 2012 – 2022
20	Gisborne District Council (2013) Gisborne CDEM Group Tsunami Contingency Plan
21	Gisborne District Council (2016) Tairawhiti Civil Defence Emergency Management Group Plan 2016 – 2021
22	Tairāwhiti Resource Management Plan 2017 - Part B - Regional Policy Statement
23	Tairāwhiti Resource Management Plan 2017 - Region Wide Provisions
24	Gisborne District Council (2015) Tairāwhiti First! 2015-2025 Long Term Plan
25	Gisborne District Council Hazard Risk Profile 2015
26	Wellington Region Emergency Management Group (2013) Wellington Region Civil Defence Emergency Management Group Plan 2013 – 2018
27	Wellington CDEM Group Distant Source Evacuation Plan
28	Greater Wellington Regional Council (2013) Regional Policy Statement for the Wellington Region
29	Greater Wellington Regional Council (2000) Regional Coastal Plan for the Wellington Region

30	Greater Wellington Regional Council (2004) Wairarapa Coastal Strategy
31	Napier City Council (2015) Napier City Council Long Term Plan 2015 – 2025
32	Napier City Council (2011) City of Napier District Plan Chapter 62 Natural Hazards
33	Napier City Council (2011) Safer Napier Policy
34	Napier City Council (2016) 2016/17 Annual Plan
35	Central Hawke's Bay District Council (2015) Long Term Plan 2015 – 2025
36	Central Hawke's Bay District Council (2003) Central Hawke's Bay District Plan
37	Hastings District Council (2015) Proposed Hastings District Plan
38	Hastings District Council (2012) Hastings District Plan
39	Hastings District Council (2000) Hastings Coastal Environment Strategy Technical Paper #4
40	Hastings District Council Hastings Coastal Environment Strategy (in HDC 2015 proposed plan)
41	Hastings District Council (2014) Local Governance Statement
42	Hastings District Council (2013) Waimarama Community Plan
43	Hastings District Council (2015) Long Term Plan 2015-25
44	Hastings District Council (2016) Annual Plan 2016-2017
45	Wairoa District Council (2005) Wairoa District Plan
46	Wairoa District Council (2014) Significance & Engagement Policy
47	Wairoa District Council (2004) Wairoa Coastal Strategy
48	Wairoa District Council (2015) 2015-2025 Long Term Plan (LTP)
49	Wairoa District Council (2016) Wairoa District Council Annual Plan 2017/18
50	Hutt City (2015) Long Term Plan 2015-2025
51	Hutt City (2016) Annual Plan for 2016-2017
52	Hutt City (2016) City of Lower Hutt District Plan
53	Wellington City Council (2017) District Plan
54	Wellington City Council (2015) Long-term Plan 2015–25
55	Wellington City Council (2015) Annual Plan 2016/17
56	Wellington City Council (2016) 100 Resilient Cities Preliminary Resilience Assessment
57	Wellington City Council (2011) Towards 2040: Smart Capital Strategy
58	Wellington City Council (2014) Draft Wellington Urban Growth Plan 2014 – 2043