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Social Vulnerability Indicator Breakdown

on

Disaster Risk Management Actions

An Approach to Identify Demographic Social Vulnerability Indicators

Prior to Disaster Occurrence

Analyzing Individual Natural Warning Response

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ABSTRACT

This paper discusses the sequential conceptualization of Social Vulnerability Indicators (SVI), using disaster risk management phases to assign them. Two hypothesized models are used to identify SVI for the 'Warning' phase, the temporal sequence prior to the potential disaster impact. One model uses demographic variables, the other uses intra and interpersonal variables, to provide a comprehensive view on possible indicators, influencing social vulnerability on an individual level. The case study was conducted in Canterbury, New Zealand, in 13 coastal areas, prone to tsunamis and gathered data about peoples' experience and behavior in the 2010/11earthquakes. The physical presence of people in these areas, immediately following the earthquakes, determines vulnerability to a potential locally generated tsunami, influenced by social factors. Ground shaking acted as a natural warning mechanism, which enabled people to alter vulnerability by controlling their exposure, when implementing evacuation as a response. A survey using a personally administered questionnaire was conducted, and gathered data from 127 people, randomly approached in 130.5 hours. The hypothesized models were analyzed using structural equation modeling (AMOS v. 20), and identified the interpersonal variable, 'Observed Response of Others', as most influencing. This finding suggests that peoples' actions, in order to deal with potential hazards, are orientated on the behavior of others, rather than on intrapersonal factors. A further analysis of peoples' earthquake perception, implies that earthquake duration, which is used as a decisive indicator for self evacuation, cannot be accurately estimated in the case of extreme events. The presented conceptualization of SVI, regarding their related disaster risk management phases, allows an allocation of SVI into eight phases, which are coherent to temporal disaster risk management activities, and therefore enables indicators to be more informative.

Key Words: Risk, Social Vulnerability, Natural Warning Response, Human Behavior, Evacuation, Disaster Risk Management Cycle, Canterbury Earthquakes, New Zealand.

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For the case study, the extent and content of natural hazard information provided to people in Canterbury had to be analyzed, whereby hazard analyst HELEN GRANT (Environment Canterbury), and the civil defense and emergency managers: DON GEDDES (Ashburton District), MURRAY SINCLAIR (Christchurch City District), and BRENNAN WIREMU (Waimakariri District), declared themselves willing to talk personally with me about previous and current practices. I would like to express my gratitude to these people, for their offered help.

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1. INTRODUCTION

The objective of this study is to demonstrate a way of social vulnerability indicator (SVI) identification and categorization in order to make future research better comparable. A case study is conducted to show an approach of SVI identification and to highlight problems using indicators, without specific meaning for disaster risk management. Risk management phases displayed on the disaster risk cycle and SVI allocation, enable us to study social vulnerability, breaking down its meaning at a certain point in time. The objective of the case study, is to identify SVI for the disaster risk management phase 'Warning' using two hypothesized models . The first model aims to identify demographic variables and the second model uses proposed intra- and inter personal indicators for this purpose. For the practical implementation of this research, the case study tries to analyze natural warning behavior and current public hazard information and management programs. A further objective is to understand what drives human behavior when facing hazard-risks, as it is an essential step in creating more disaster resilient communities. Most studies regarding social vulnerability measure post-disaster aspects of individuals or communities coping with the disaster, whereas this study focuses on the identification of indicators which are socially determined and contribute to potential physical disaster exposure.

Appropriate disaster risk management activities needs to be efficient and target orientated. Risk reduction is essential for reducing losses in lives, health status, livelihoods, assets and/or services. The reduction of vulnerability can be seen as an important task (Rygel et al., 2006) to limit negative effects of a hazardous event on a society. For the purpose of this reduction, indicators for social vulnerability have to be identified, which is a main aim of the case study presented in this paper. Further, an approach to organize and conceptualize social vulnerability indicators (SVI) and social vulnerability research is provided, in order to help future field research be better comparable. The paper also aims to draw conclusions for the local emergency and civil defense management agencies from the case study, in order to pinpoint risk management strategies.

The introduction encompasses the basic theoretic principles of social vulnerability analyze and stress the need for the proposed social vulnerability indicator conceptualization approach constructed on the risk management cycle. A phasing-in the concept of disaster risk is followed by a short historical overview of vulnerability assessment, which depicts the prerequisite to investigate the concept of social vulnerability. An overview of previously gathered SVI is used to identify demographic conditions influencing social disaster risk, which allows the introduction of the conceptual social vulnerability indicator categorization on the disaster risk management cycle. The theoretical part of the introduction closes with a description of the suggested natural warning response model (NWRM) to explain socio-psychological influences on the SVI.

The following case study uses an earthquake acting as natural warning and trigger for a possible tsunami, to identify SVI with the main purpose to determine social vulnerable demographic groups. For this purpose a personal administered questionnaire gathered in 130.5 hours data about 126 random selected respondents living in 13 coastal regions exposed to the potential hazard. Structural equation modeling is used to test two models for indicator identification; one which uses demographic data, and one which uses intra/inter-personal data to explain natural warning response.

1.1. THEORETICAL CONCEPTS OF DISASTER RISK

This chapter introduces theoretical concepts and interpretations of risk, social vulnerability, natural warning response and its related indicators, to provide background knowledge for this paper and its underlying concepts. Interpretations of risk and vulnerability vary, and can be seen from different perspectives, which makes it hard to find definite and generally accepted definitions of these concepts. To provide an understanding of way social vulnerability is seen in this paper, this chapter starts with the definition and approach to disaster risk.

1.1.1. DISASTER RISK

The concept of risk is very complex, as it represents something unreal, by relating to random chance and possibility (Cardona et al., 2003). This paper defines risk in disaster management according to Blaikie et al. (1994) as the cumulative impact of hazard and vulnerability:

$$\text{Risk (R)} = \text{Hazard (H)} \cdot \text{Vulnerability (V)}$$

The loss or realized disaster risk R, is the product of the probability of occurrence of a specific hazard H, in a given area over a given time period, and the degree of loss resulting from the occurrence of the phenomenon, which is defined as vulnerability V (Blaikie et al., 1994). The assessment of risk is a prerequisite to manage risk and takes the expected physical damage, victims, economic equivalent loss, social, organizational and institutional factors into account (Cardona, 2004). However, the concept and definition of vulnerability is elaborated further in detail in the next chapter, whereby a hazard is defined in this paper as:

A dangerous phenomenon, substance, human activity or condition that may cause loss of life, injury or other health impacts, property damage, loss of livelihoods and services, social and economic disruption, or environmental damage. (UNISDR, 1999, p.17)

Although this case study uses a potential hazard of natural origin, a general definition is chosen, as a risk of any origin can be analyzed with the conceptualization and analysis approach, presented in this paper. A disaster is defined as:

A serious disruption of the functioning of a community or a society involving widespread human, material, economic or environmental losses and impacts, which exceeds the ability of the affected community or society to cope using its own resources (UNISDR, 2009, p.9).

Consequently, disaster risk is seen as the outcome of continuously present conditions of risk, which can be defined as:

The potential disaster losses, in lives, health status, livelihoods, assets and services, which could occur to a particular community or a society over some specified future time period (UNISDR, 2009, p.9).

As mentioned there exist varying interpretations of risk. The purpose of this paper is not to analyze different approaches, however Crichton's (1999) risk expression is interesting to cite, to reveal a fundamental principal this paper is underlying. This risk approach, used in other studies analyzing social vulnerability (e.g. Dwyner et al., 2004), views risk as the probability of a loss, whereby this is dependent on the elements hazard, vulnerability, and exposure:

$$\text{Risk} = \text{Hazard} \cdot \text{Vulnerability} \cdot \text{Exposure}$$

If any of these elements, which can be diagrammed as a three-dimensional pyramid, increases or decreases, then risk increases or decreases respectively (Crichton, 1999). This paper renounces from this approach as it is hypothesized that vulnerability itself is dependent on exposure, hence exposure cannot be seen as a separate factor of risk. The reasoning for renouncing this approach is elaborated in detail, when the case study is presented later on. At this stage it is sufficient to understand that physical exposure may influence social vulnerability in some instances, and can therefore not be seen as a separate element within the risk function.

The discussion of the disaster risk definition leads to the question: How do people deal with risk? To reduce risk, risk managers try to limit existing risks by changing the variables of hazard and vulnerability. For the desired reduction, risk has to be assessed, whereby risk assessment is defined as:

A methodology to determine the nature and extent of risk by analysing potential hazards and evaluating existing conditions of vulnerability that together could potentially harm exposed people, property, services, livelihoods and the environment on which they depend (UNISDR, 2009, p.26).

Once the potential hazards are analysed and according conditions of vulnerability evaluated, certain risk management activities are used to deal with risk. In this paper risk management is defined as:

The systematic approach and practice of managing uncertainty to minimize potential harm and loss (UNISDR, 2009, p.26).

The goal of this management would ideally lead to a risk of zero, but as this is not possible, people deal with an acceptable level of risk. Hence, the level of risk is 'good enough' when the advantages of increased safety are not worth the costs of reducing risk by restricting or otherwise altering the activity (Slovic et al., 1978). Therefore the goal of risk management can be seen as aiming to minimize the losses caused by the event and the minimisation of the protection costs for the achievement of this goal. In an equation this economically based risk management approach appears as:

$$\text{Min}\{\text{Total\_Costs}\} = \text{Min}\left\{ \int_{x^*}^{\infty} (f(x) \cdot D(x) \cdot d(x) + C\,(x^*) \right\}$$

Wherby the event probability [f(x)] times the event consequences [D(x)] plus the costs for protection [C(x*)], should be minimized. This principle can lead to difficulties when managing risk following the equity principle in a society, as following this equation risk management actions are more appropriate in areas where the damage reduction is greater. This approach can lead to activities which prefer to invest in any kind of protection, where the damage potential is greater. Shortly stated, 'richer' areas, with more damage potential may be prefered when investing in risk protection activities, than areas with less damage potential. Hence poorly developed areas could become more risky to live in, which would not comply with the equity principle, to treat all members of a society the same, and hence deserve the same level of protection. But as risk assessment and not risk management is main goal of this paper, this will not be further discussed.

Sometimes it is impossible to reduce the hazard,therefore a promising limitation of disaster-risk can be achieved by the reduction of the factor vulnerability. For example, the hazard of an earthquake is mostly regarded as impossible to alter, whereby the vulnerability of the objects at risk can be altered. Facing other hazards, e.g. floods, allows the alteration of the hazard occurence itself, by changing hazard frequency, for example building dams, and the vulnerability of the objects at risks can be altered. This example demonstrates that appropriate risk management activities need to be planned and developed systematically for each risk specifically. Each consequent decision faces certain economic, social and environmental objectives, which need to be balanced. This paper focuses on the promising approach to identify and therefore allowing management of certain vulnerabilities. Vulnerability estimation and reduction must be seen essential for effective risk reduction (Birkman, 2006a). The following chapter introduces the origin of vulnerability and its approaches.

1.1.2. VULNERABILITY

Formerly, natural hazards were identified as the cause of vulnerability. Therefore, it can be said that people who live in endangered zones are exposed to a higher risk, than those living in ´safe´ areas. Scientists, technologists, and engineers have attempted to predict natural hazard events and developed technologies that enable human structures and systems to withstand their impacts. It is believed that vulnerability could be reduced, if the society could more accurately predict where, when and in what magnitude these events will occur and by the development of mitigation technologies. This approach could be identified as 'natural cause approach', created by scientists who focus on the technological or engineering aspects of a natural hazard (Anderson, 2000).

Another approach could be called the 'costs as cause approach' , created mostly by economists, who assess how much vulnerability reduction is rational. Economically rational criteria for deciding which vulnerability-reduction technologies should be used under what circumstances, have been developed for this purpose. Focused on the fact that although vulnerability has its costs in terms of losses of life, health and property, vulnerability reduction has costs as well. Economists have developed systems for measuring cost-benefit ratios when applying the various technologies available for reducing vulnerability. Within this development, economists have recognized that the understanding of vulnerability must expand to incorporate an increasing number of variables. Experience shows that vulnerability to loss of life, health and poverty, varies widely among people who experience the same disaster, and also among those who experience disasters of the same size and scope, at different times in different parts of the world. It was thus concluded that more than just hazard and exposure must be considered to accurately assess vulnerability. The 'humans as cause-approach', where social scientists, policy reformers, advocates for the poor, and environmentalists all deal and assess vulnerability, was born. Important to notice is that the central role of humans in creating vulnerability, has integrated additional variables into their definitions of vulnerability (Anderson, 2000). Disasters are therefore not primarily physical occurrences which require technological solutions, but are viewed as a result of complex interaction between a potentially damaging physical event and the vulnerability of a society, its infrastructure, economy and environment, which are determined by human behavior (Birkman, 2006a). This change of view on vulnerability leads to the conclusion that the reduction of the pressure of natural risk, given by a certain hazard by reducing the level of vulnerability to which human communities are exposed, has become an efficient and accessible way of risk management.

The key spheres of vulnerability shown in Figure 1, illustrate the complexity of this concept, and the problem to find a common definition (Birkman, 2006a). The inner circle can be seen as common ground, whereby the second one identifies the human centered definition of vulnerability of the likelihood of death, injury and loss. The middle circle represents the dualistic approach which can be extended to the multi-structural circle, consisting of susceptibility, coping capacity, exposure, and adaptive capacity.

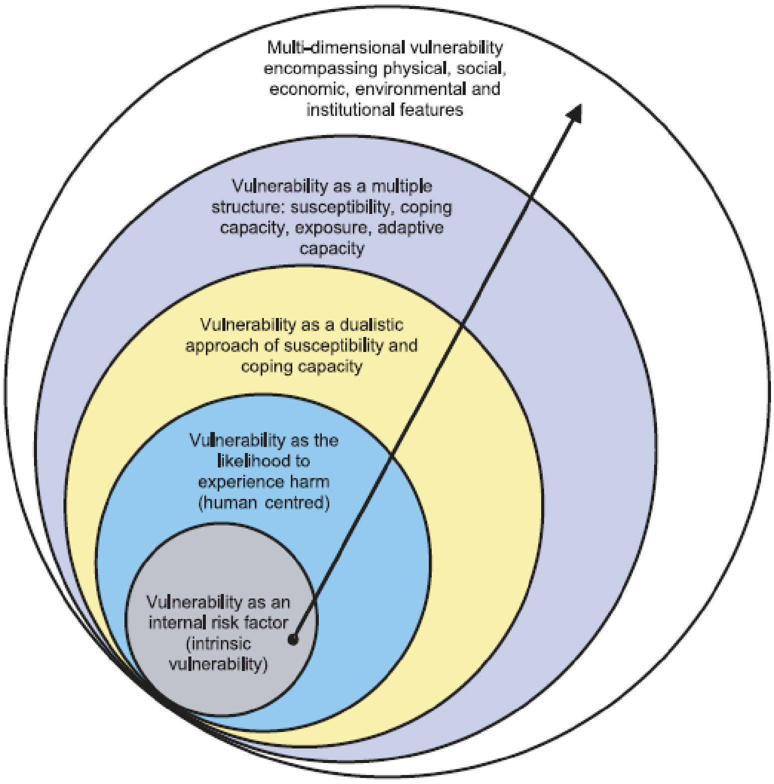


Figure 1: The key spheres of vulnerability
Source: Birkman, 2005

The outer, fifth circle of vulnerability is seen as multi-dimensional and encompasses physical, social, economic, environmental and institutional features (Birkman, 2005). According to Cardona et al. (2003) the dimensions of vulnerability reach further than shown in Figure 1 and include additional dimensions; institutional, political, cultural and ideological. However, this illustration highlights the shift of vulnerabilities perspective from a primarily physical structure analysis to a broad interdisciplinary analysis approach (Birkman, 2005).

Due to the complex nature of vulnerability, many definitions exist with a variety of contexts and meanings. For the purpose of this study, vulnerability is defined following the United National Development Program as:

A human condition or process resulting from physical, social, economic and environmental factors, which determine the likelihood and scale of damage from the impact of a given hazard (UNDP, 2004, p.11).

Important to point out is that the UNDP refers to the above mentioned dimensions of vulnerability as factors and does not define the structural part in detail. The development and meaning of vulnerability has initiated a discussion regarding different conceptual and analytical frameworks on how to systematize vulnerability. This process has brought up at least six different frameworks, and two different schools explaining the approach to social vulnerability, whereby each is created for a different purpose and each has its limitations in use (Birkman, 2006a). Since vulnerability itself faces such a complexity, most assessment approaches use 'relative' views of vulnerability, where comparisons and interpretations of vulnerabilities between different groups, entities and geographic areas are made (Birkman, 2006b). As the main aim of this paper is to identify SVI, a relative view on social vulnerability is followed, in order to identify the demographic groups most at risk.

In summary, it can be stated that vulnerability is a complex system, used for different purposes and is conceptualized differently. As this chapter has outlined, vulnerability can be dependent on many variables, and different structures in different dimensions. To strengthen the link between vulnerability and disaster research, it can be stated that: The tendency for a disaster to occur is dependent on the interplay between humans and their use of the physical and social world. If so, disasters can be seen to be an expression of the vulnerability of the human society (Britton, 1986) and to assess vulnerability is therefore seen as an important task (Rygel et al., 2006). People live mostly in social environments while facing some form of physically generated hazards, which influences their vulnerability by social conditions. The next chapter provides an introduction into this concept and highlights the main challenges related research faces, in order to understand the concept of social vulnerability to reduce risk.

1.1.3. SOCIAL VULNERABILITY

The concept of social vulnerability lacks a common definition (Birkman, 2006a), which makes it hard to compare between different research areas. This paper interprets social vulnerability as a dynamic process, which is rooted in the actions and multiple attributes of human actors. It is influenced and driven by multiple stresses, manifested simultaneously on more than one scale, often determined by social networks in social, economic, political and environmental interactions and faces, it is exposed to stresses experienced or anticipated by the different units exposed (Downing et al., 2006). This complex concept of social vulnerability leads to a certain complexity in the selection of representative indicators, which will be discussed further in the next chapter.

Birkmans´ (2006a) comparison of the two main schools of social vulnerability thinking, highlighted the commonness that "*Social vulnerability should not be seen limited to an estimation of the direct impacts of a hazardous event. Rather it has to be seen as the estimation of the wider environment and social circumstances, thus enabling people and communities to cope with the* *impact of hazardous event.*"(Birkman, 2006a, p.14) Underlying this principle of social vulnerability, coping capacity and resilience of the potentially affected society are also included in social vulnerability (Birkman, 2006a). The different understanding of the resilience concept still prevails in disaster literature (Engle, 2011) which makes it hard to find a general acknowledged definition of it. Current literature for resilience reveals different interpretations, whereby in general a census can be seen in the understanding that resilience describes the capability of a system to maintain its basic functions and structures in a time of shocks and perturbations, which implies that this system is able to cope, learn, and adapt (Birkman, 2006a). Adaptive capacity of a system, seen as medium and long term strategies for changes in institutional frameworks (Birkman et al., 2009) allows us to see coping capacity as the short term strategy to an immediate occurring risk. This is an important aspect as it constitutes an essential part for the categorization of SVI's on the disaster risk cycle, which is illustrated in Chapter 1.1.5. The aim of this chapter was to highlight the complexity of the concept of social vulnerability, leading to a certain degree of complexity in its indicator identification, which is elaborated in the next chapter.

1.1.4. SOCIAL VULNERABILTIY INDICATORS (SVI)

One of the major obstacles social vulnerability indicator research faces, is that the social science community agrees on the influences of social vulnerability, but disagreement arises in the selection of specific variables to represent these broader concepts (Cutter, Boruff, & Shirley, 2003). As the determination of vulnerability is an essential prerequisite to reduce disaster risk, and requires the ability to identify and understand the various vulnerabilities to hazards determining risk (Birkman, 2006b), the identification of suitable vulnerability indicators is seen as essential for risk reduction. The important task to assess vulnerability (Rygel et al., 2005), makes it inherent to select an appropriate indicator to present the concept of social vulnerability. Cutter, Boruff, and Shirley (2003), stated that there is a clear need to develop robust and replicable sets of conceptual understandings of comparative indicators of social vulnerability. Further, social vulnerability indicator research largely derives from local case studies of disaster and community responses (Cutter, Boruff, & Shirley, 2003), hence indicators are hard to compare and dependent on underlying case study methodology. The idea behind the suggested conceptualization of SVI, which will be elaborated further on, is to overcome this problem of case study specific methodology. The conceptualization approach aims to generate a framework in which local case study research is designed to allocated indicators for a certain time in the risk management process, which should make its indicators more meaningful.

This will be part of the next chapter, however, an indicator development process should be goal orientated and formulate these specifically. Standard criteria for indicators found in literature include, to encompass their ability to be: measureable, topic and policy relevant, key-element orientated, analytical and statistically sound, understandable, easy interpretable, sensitive and phenomenon specific, valid and accurate, reproducible, based on and comparable to available data, cost effective and within appropriate scope (Birkman, 2006b). Whereby Birkman (2006b) orientates his definition of indicators on natural hazards, this paper uses this interpretation of indicators for hazards of any kind as disasters are too defined as independent of their cause. Following, an indicator is defined as:

A variable which is an operational representation of a characteristic or quality of a system able to provide information regarding the susceptibility, coping capacity and resilience of a system to an impact of an albeit ill-defined event linked with a hazard (Birkman, 2006b, p. 57).

Previously identified demographic SVI are listed in Table 1, whereby their relevance to their disaster management phases is shown and will be elaborated in more detail in the next chapter. Only indicators of demographic nature are listed, because these are believed to fulfill most of the standard criteria for indicator selection. Due to the difficulties in comparing indicators others than those of a demographic nature, the main purpose of this paper was chosen to identify demographics.

However, in Table 1 it is not attempted to deliver a comprehensive register of all demographic SVI developed, but rather to establish a connection between SVIs and their meaning to a specific disaster risk management phase. Table 1 also includes general statements (e.g. economic prosperity: "People who live in poverty are in general more vulnerable than wealthy people to disaster") about indicators, whereby these cannot be specifically allocated to a disaster phase, they represent research findings about the indicator itself. A side remark can be stated that this paper suggests a function of the phases-allocated-SVI, to generate a reliable general conclusion about e.g. a communities social vulnerability. Rather than to make a general statement without consideration for its meanings for all of the disaster risk management phases.

Demographic Social Vulnerability Indicators				
Indicator	**Description**	**Sources**	**Detail**	**Disaster Management Phases**
Economic Prosperity	People who live in poverty are in general more vulnerable than wealthy people to disaster. Poor people have less money to spend on preventive measures, emergency supplies and recovery efforts. Further the poor suffer from higher mortality rates and from greater housing damage, during disasters. The economic and material losses sustained by the poor are more devastating in relative terms, than those of the wealthy. During disasters the poor are less likely to have access to lifelines, such as communications and transportation.	Blaikie et al. (1994) Clark et al. (1998) Morrow, (1999) Fothergill and Peek (2004)	People living in poverty	Preparedness Emergency Response Recovery Disaster Occurrence
Sex	Woman are more likely to face difficulties after disaster than men often due to lower wages. Especially divorced mothers and never-married mothers, are more likely to live in poverty and are therefore more vulnerable to disasters than men. Furthermore woman are more likely to have a role as caregivers which restricts their ability to seek safety when disasters strike, due to their responsibility to help others. They are more easily trapped by their responsibilities towards children and elders when trying to preserve their own safety.	Blaikie et al. (1994) Bianchi and Spain (1996) Cutter (1996) Fothergill (1996, 1998) Enerson and Morrow (1997,1998) Hewitt (1997) Enarson and Scanlon (1999) Morrow (1999) Peacock, Morrow, and Gladwin (2000)	Women	Disaster Occurrence Disaster Recovery Warning
Age	Elderly are in general more likely to lack the necessary physical and economic resources to effectively respond to a disaster. Furthermore economic and material support often lacks in the case of disasters. Elderly are more likely to suffer health-related repercussions and therefore recover more slowly. Older people tend to be more reluctant to evacuate and are more likely to have physical difficulties which hinders evacuation. Furthermore older people tend to be distressed by the prospect of leaving their homes and like to live in group evacuation quarters. Children who lack adequate family support face limitations in disaster response.	O'Brien and Mileti (1992) Hewitt (1997) Galdwin and Peacock (1997) Morrow (1999) Ngo (2001) Dwyer et al. (2004) Rygel et. al (2006)	Young and old	Disaster Response Disaster Recovery Warning
Family Structure	Limited financial resources lead especially for single-parent households and large families (large number of dependents) to limitations in recovery from disasters.	Blaikie et al. (1994) Morrow (1999) Puente (1999)	Single-parents and large	Disaster Recovery

		Heinz Center for Science, Economics and the Environment (2000)	families	
Education	Lower education level limits the ability to understand warning information and therefore increase vulnerability. As education is linked to socioeconomic status, a higher education level results in greater lifetime earnings and provides access to more recovery information, which decreases vulnerability.	Heinz Center for Science, Economics and the Environment (2000)	Low education level	Disaster Recovery Warning

Table 1: Demographic social vulnerability indicators

1.1.5. DISASTER RISK MANAGEMENT CYCLE FOR SVI ALLOCATION

This chapter introduces the concept of SVI allocation to disaster risk management actions. This assignation is required as disasters have distinctive effects on different subgroups of the population, and during different phases of the disaster (Amaratunga, Tracey, & O'Sullivan, 2006).Disaster management phases seen in this context are not dependent on the actual level of disaster management (individual or institutional), nor on the actual occurrence of a disaster. Figure 2 illustrates the disaster risk management cycle rather as a time cycle which illustrates phases of risk management activities, based on the probability of specific hazards

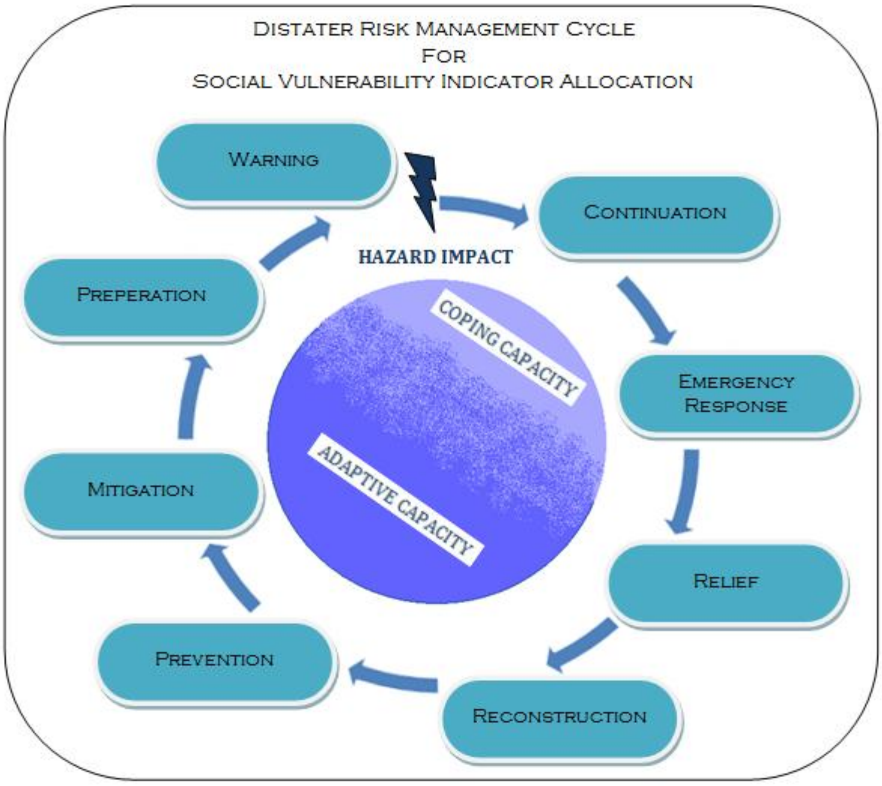


Figure2: Disaster risk managment cycle for SVI allocation

The given definition of a disaster implies that an event has to be disruptive to an extent, that more than the systems' own resources are needed to cope with it (UNISDR, 2009). By the incorporation of sociological and psychological processes, involved in decision making in order to cope with disaster risk, aspects of resource overstressing might not be appraisable. This suggests that risk management actions may be taken without the possibility to assess the actual occurrence of a state of an event. For example emergency response actions which take place immediately after an earthquake may start without knowing if the extent of the event overstressed the regions ability to deal with it, which would declare a disaster. Hence the phases on the disaster risk cycle can be regarded as not disaster dependent.

This paper is the first which restructures SVIs relating to their validity at a certain time along disaster management activities. Figure 2 illustrates the disaster risk management phases:

emergency response, relief, reconstruction, prevention, mitigation, preparation (Schipper & Pelling, 2006); warning, and continuation, arranged on a cycle whereby the time can be seen as progressing in disaster or hazard risk management activities. As mentioned in the previous chapter adaptive and coping capacity can be seen in terms of long or short term activities, in order to reduce disaster risk. The risk cycle is broadened by two phases 'event warning', prior to the possible disaster occurring, and 'continuation' which stretches from first event impact to the emergency response onset. The phase 'warning' might not be appropriate to include for every hazard, as some hazards (e.g. earthquakes) can occur without a warning period. However, for other hazard like a tsunami, flood, or volcanic eruption such a phase may act as a precedent to a disaster and has therefore to be a part of the disaster risk management cycle.. The phase 'continuation' is included to highlight specific socially generated vulnerability during the occurrence of an event. For example physical strength seemed to be crucial for survival (and therefore reduced social vulnerability), as people reported to have survived because of their ability to run uphill, or climb on trees (Bird et al., 2011). It is hypothesized that each phase enables the identification of demographic groups who are most vulnerable, and that indicators can be allocated therefore. However, the case study analyses demographic SVIs for the phase 'Warning', which will help to explore this conceptualization in more detail further on.

The case study tests also an additional second model, to identify different indicators other than demographics, to analyze influences for social vulnerability. This model is included in the study design as literature suggests that demographics can not always explain behavior differences sufficiently. The next chapter elaborates on the theoretical background for this model and introduces the basic considerations for its composition.

1.1.6. NATURAL WARNING RESPONSE

The case study uses the Canterbury earthquakes 2010/11 as a possible trigger of a tsunami, whereby the individual experience of the earthquake itself is the only warning people receive. Under this circumstance, the generated ground shaking acts as a natural warning and people in the hazard inundation zone are advised (in advance) to evacuate immediately (ECAN, 2012a). This paper states that this behavior determines peoples' vulnerability to the possible hazard tsunami and analyses its possible social influences. Displayed on the disaster risk management cycle, this social vulnerability is due to the occurrence assigned to the phase 'Warning', hence the indicators which define evacuation behavior are seen as indicators for SOVI-Warning.

When such a ground shaking occurs, the first tsunami surge could hit the coastline within 5 minutes (ECAN, 2012a), therefore people need to have the capability to respond promptly and appropriately in advance of the hazard occurring (Paton et al., 2008), in order to reduce their vulnerability. Currently, we know little about the causes of human behavior and response to the precursors of tsunamis, especially the recognition and interpretation process of these signs which leads to the response, are barely known(Gregg et al, 2006). A few observations of historic events (e.g.: Hawaii, Japan and Chile) provide just a little insight in the formation of response actions regarding tsunamis. Gregg et al. (2006) highlighted the need for this kind or research and emphasized that; without the knowledge of hazard perception and interpretation, and the formation process, which leads to response actions, it will be impossible to develop effective risk reduction strategies. To enhance the capacity in populations, which are susceptible to locally-generated tsunamis, systematic analysis of the perception and interpretation of natural warning signs is required (Gregg et al., 2006).

The natural warning response has sometimes to deal with two forms of response, which makes the analyze more complex. On one hand, people have to deal with the hazard which acts as a warning and on the other hand, people need the ability to interpret these natural event as a warning towards possible future hazards. In order to explain how people respond to an extreme event, Burton et al. (1993) states that people examine the ways in which they recognize and describe a hazard, consider how they might deal with it, and consequently choose among actions that seem to them available. As in this case study, the earthquake serves as a natural warning, the first step of recognition and description of the hazard is equal to those of the warning itself. Figure 3 illustrates the suggested natural warning response model (NWRM), which uses the indicators hazard risk perception, hazard knowledge, response outcome expectancy and warning perception to describe this first step in response building process.

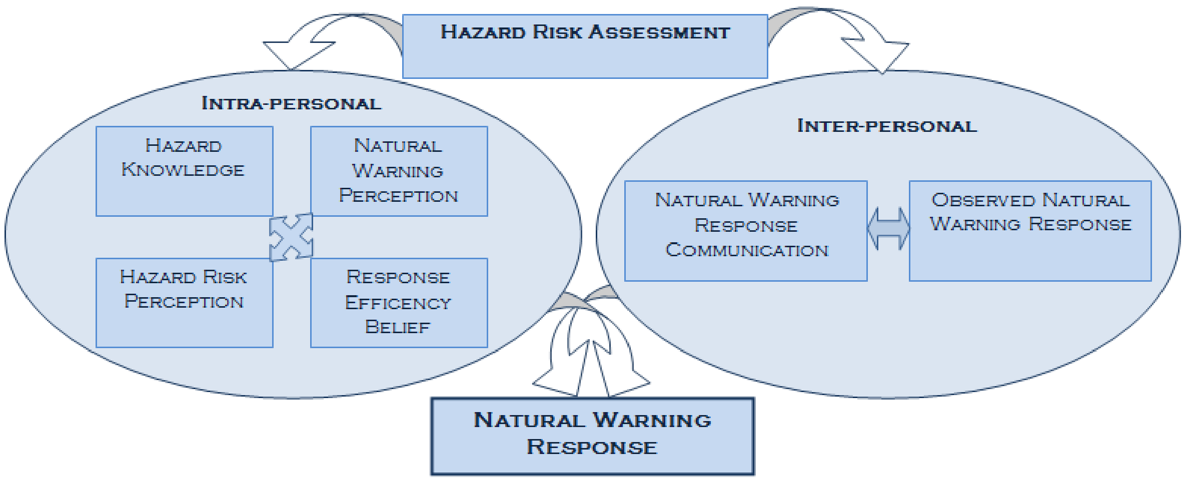


Figure3: Natural warning response model

It is hypothesized that people need to understand the hazard warning, have an adequate risk perception, a certain degree of hazard knowledge, and hold a positive belief in the effectiveness of their own actions in order to respond appropriately to the natural warning.

The indicator 'risk perception' is probably the most complex to gather as: *risk means different things to different people* (Slovic, 2000, p.189). Risk perception seems to derive from fundamental modes of thought and once formed, initial impressions intend to structure the way that subsequent evidence is interpreted (Slovic, 2000). The mental models people use to judge risks are internalized through social and cultural learning and constantly reinforced, modified, amplified, or attenuated by the media, peer influences and other forms of communication (Morgan et al., 2001). Risk perception includes processes of collection, selecting and interpreting signals about uncertain impacts of events, whereby these perceptions may differ depending on type and content of risk, the individuals personality characteristic and the social context (Wachinger & Renn, 2010). Furthermore, it is by some researchers regarded as the main factor contributing to a person's social vulnerability, in terms of disaster recovery (Dwyer et al., 2004).

As Figure 3 shows, the indicator hazard knowledge is included in this model, as people need to have a basic understanding of the hazard in order to respond to it adequately (Gregg et al., 2006). Relevant for the hazard tsunami it can be mentioned that people who lack understanding of the hazard are not able to identify safe ground. People tend to underestimate the inundation area and the force of the water, or the unavailability of high points which could serve as safe spots (Gregg et al., 2006).

The model incorporated the indicator of hazard control beliefs about the efficacy of protective actions, which uses the construct of outcome expectancy. This construct is also used to assess peoples level of hazard preparedness (Paton, 2008; Paton et al., 2008) and is regarded as essential for the suggested model as this indicator estimates peoples believe in the efficiency of personal counteractions, to deal with the hazard. The indicator can be seen as a combination of behavioral beliefs (beliefs about the likely outcomes of the behavior and the evaluations of these outcomes) and control beliefs (perceived power of behavior). Both beliefs are used in the theory of planned behavior, by Ajzen (1991) and are therefore regarded as essential to include in the NWRM.

The last indicator used to display the individual risk recognition and description phase is warning perception, as it is hypothesized that the degree in which the warning is experienced, may be an important influence for the risk assessment. Individual risk perception is related to the quantitative assessment of characteristics of the hazard faced (Slovic, 2000), which leads to the conclusion that a hazard has to be identified in the first place in order to perceive it as a risk. For the case study, this warning experience is addressed as the experienced length and strength of the earthquake, which might lead to the recognition of it as a natural warning.

As Figure 3 illustrates the suggested NWRM uses the above described 4 indicators for the intra-personal hazard risk assessment. This 'independent' assessment, which may lead to risk management actions, might be altered by so called intra personal influences. To measure this influences the indicators Natural Warning Response Communication, and Observed Natural Warning Response are chosen. The inclusion of external influences is crucial as peoples' risk mitigation activities are influenced by the information of others, when they face complex and uncertain events (Lion et al., 2002). This suggests that risk reduction actions in the warning phase might also be influenced by the actions of others.

The detailed definition of the indicators used to describe this model can be found in Chapter 2.2.2., whereby following the introduction to the conducted case study to identify SVI for the warning phase is mentioned below.

1.2. CASE STUDY

The case study analyzes social vulnerability at an individual level of Canterbury's coastline residents after the Darfield earthquake, which occurred on the 4th September 2010. When the 7.1 earthquake and three following major aftershocks 2011 struck, Canterbury's coastline residents were exposed to the theoretical threat of a local generated tsunami following the quakes. The major earthquake and the aftershocks hit with a magnitude which could potentially generate a tsunami (Geonet, 2012a) and therefore represent a natural warning in forma of ground shaking, to which Canterbury's coastline residents are advised to respond with evacuation (ECAN, 2012b). The detailed criteria for the essential experienced ground shaking intensity and duration, to regard it as a natural warning, are defined by the responsible emergency management authorities and are elaborated in more detailed later, as they differ. Generally speaking people located in the tsunami inundation zone, were able to alter their social vulnerability by evacuation, which would theoretical determine physical exposure to the potential hazard. The lack of systematic studies to identify and explain the ways in which individuals observe and respond to hazards and how they interpret natural warning signs (Gregg et al., 2006), highlights the importance of the suggested case study design. People in the settlements of the Waimakariri, Christchurch City, and Ashburton districts are surveyed with a personal administered questionnaire in June and July 2012. Since this research uses an actual behavior in regards to a potentially devastating tsunami (Owens et al.,1994) with the advantage that a disaster never occurred, it is possible to study both, 'survivors' and 'victims', which should allow a comprehensive perspective.

1.2.1. STUDY SITE DESCRIPTION

Figure 4, shows 13 study sites located in the Canterbury region on the south island of New Zealand, in the Pacific Ocean, which are chosen to be the subject of this case study. This sites are located in the potential tsunami inundation zones on the coasts of the districts Waimakarii, Christchurch City and Ashburton. These zones are identified with the conduction of personal interviews with the emergency management authorities in the districts Waimakarii (B. Wiremu, 14. June 2012) and Ashburton (D. Geddes, 13 June 2012) as no public information was available in these districts. For the Christchurch City district an inundation zone map on a public folder was used for the same purpose (see Appendix 1).

Figure 4: Study site map
Source: Altered from Freshmap, 2012

These coastal settlements are prone to the hazard of a locally generated tsunami (Berryman, 2005), which generates a certain degree of risk for the people living in this area. None of the earthquakes since September 2010 have created a tsunamis, however they generated the physical conditions for a natural warning towards locally generated tsunamis. The Civil defense agencies, which are responsible for hazard warnings recommend that the experience of a strong ground shaking should be interpreted as tsunami warning and people are advised to evacuate (ECAN, 2012a). There are slight differences in the extent of ground shaking and magnitude, which has to be experienced, to interpret the event as a natural warning, between the three districts, which will be elaborated in Chapter 2.2.2.4. The overall base for the study site selection builds the felt earthquake report map for the Darfield quake illustrated in Figure 5. The map uses the reported felt earthquake experience, which is depicted in form of a simplified Modified Mercalli Intensity Scale to show the level of earthquake effect per area. The two inner circles illustrate the area experienced the quake at a scale level 7 or 8. This intensity is described as hard to stand up (Geonet, 2012b) and is used as basic criteria for study site selection. The specific criteria which are determining to identify an earthquake as natural warning varies between the districts, which posed a difficulty and are elaborated later on.

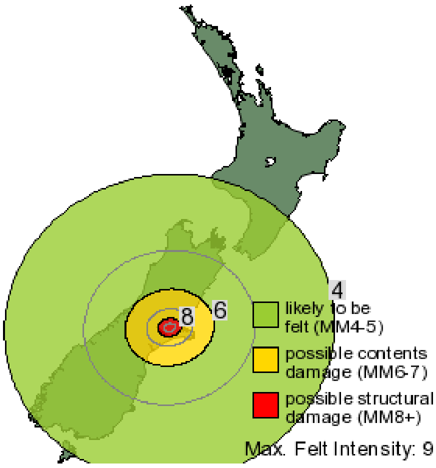


Figure 5: New Zealand earthquake report - Sep. 4th 2010 at 4:35 am
Source: Genoet, 2012c

1.2.2. DARFIELD EARTHQUAKE AND AFTERSHOCKS

Every year around 15,000 earthquakes are located in New Zealand, and 100 to 150 of these are big enough to be felt (GNS, 2012a). On the 4th September 2010 at 4:35 am an earthquake with the magnitude 7.1 struck the Canterbury region of New Zealand's south island. The quake epicenter was 40 km west of Christchurch City, southeast of the town Darfield. The quake was the most damaging earthquake in New Zealand for over 75 years (GNS, 2012b).It generated the strongest earthquake ground-shaking ever recorded in New Zealand (GNS, 2012b) and lasted for 40 seconds (PCEE, 2011).

To allow the assessment of a possible temporal change of natural warning behavior the 3 major aftershocks which struck Canterbury 2011 (Geonet, 2012d), in this research.

- On the 22nd of February a devastating magnitude 6.3 earthquake struck southeast of Christchurch (GNS, 2012c).
- On the 13th of July a magnitude 6.4 earthquake struck southeast of Christchurch (GNS, 2012d).
- On the 23rd of December a series of aftershocks stuck east of Christchurch off the coast of New Brighton. This series of aftershocks rolled on throughout the afternoon and overnight the strongest was a magnitude 6.0 earthquake at 3:18 pm (Geonet, 2012e).

As mentioned earlier, none of these earthquakes generated a tsunami (ECAN, 2012a), but the physical potential for its generation was given (Geonet, 2012a).

The following chapter elaborates on the tsunami risk to which the study sites are exposed, to allow a better understanding of the formation of public hazard information, risk management approaches, and ultimately its implications for natural warning behavior and its meaning to social vulnerability.

1.2.3. TSUNAMI RISK IN CANTERBURY

The word tsunami originates from the two Japanese hieroglyphs, translated together as "wave in the harbor" and has been conventionally adopted in scientific literature (Levin & Nosov, 2009, p.2). Tsunamis can be generated by seismic motions of the sea floor, underwater slides, collapses, or volcanic eruptions. Waves exhibiting similar characteristics may also be caused by sharp changes in the atmospheric pressure, powerful underwater explosions or meteorites falling in the sea. Important to notice is that combination of the above mentioned events might trigger a tsunami (e.g. an underwater-slide provoked by an earthquake), although the main cause of a destructive tsunami is a sharp vertical displacement of parts of the sea-floor caused by a strong underwater earthquake (Levin & Nosov, 2009). New Zealand has experienced 10 tsunamis exceeding more than 5 meters since 1840 (GNS, 2012a), during these events, a few lives have been lost and damage to property and infrastructure has been modest (Berryman, 2005). The general state of knowledge in New Zealand about the severity and frequency of tsunamis is due to the relatively young research quite poor, although the country is considered to be quite vulnerable to the hazard tsunami (GNS, 2012a).

In New Zealand, scientists distinguish between “far-or distant– source” tsunamis, which can be caused by Pacific-wide events and “near- or local-source” ones, generated by large offshore New

Zealand earthquakes, landslides, and volcanic eruptions (Searle, 1994). More recently, tsunamis are categorized according to their formation in:

- "Distant source - more than 3 hours travel time from New Zealand
- Regional source - 1 to 3 hours travel time from New Zealand
- Local source - 0 to 60 minutes time to the nearest New Zealand coast" (Berryman, 2005, p.19).

Canterbury's coastline is at risk from all sources (ECAN, 2012b), and in general it can be stated that any coastline of a large water reservoir is potentially prone to the hazard tsunami (Levin & Nosov, 2009). The distinction of tsunamis made by their geographical formation is linked to the warning time, people can be given in order to evacuate coastal areas.

New Zealand does not have any warning system for local source tsunamis, as the time taken to calculate the location of the earthquake and therefore issue a warning, before the tsunami could reach the coast is to less to issue an appropriate warning (ECAN, 2007; Owens et al., 1994; GNS, 2012a). The time between the earthquake generation and it hitting the shore, can be as short as a few minutes, therefore the only warning people in New Zealand have is a strong earthquake or the ocean behaving unusually (ECAN, 2007). For a regional source tsunami, it may be possible to issue an official warning, however, the most important warning will be the long moderate ground shaking from the earthquake itself (ECAN, 2012a).Whereas for a distant source tsunami, an official warning will be issued and people have hours to leave the tsunami inundation areas (ECAN, 2007; ECAN 2012a).

Owens et al. (1994) mentions in a research report for the Canterbury region that no instances of locally generated tsunamis have been recorded and therefore the main concerns for this region are distant generated tsunamis. A tsunami risk report undertaken in 2005 states that paleo-tsunami deposits have been found at Canterbury's coastline, which lead to the conclusion that 2 events have been triggered wave heights exciding 6 meters, in the last 4000 years (Berryman, 2005), whereby the source of these events cannot be determined. However, tsunami waves generated by a local source can arrive at nearby shores within minutes and do not need a large source to be damaging at nearby shores (Berryman, 2005). The chances of a local source tsunami being generated are low and have not changed significantly as a result of the Darfield earthquake and aftershocks (ECAN, 2012c).The risk of a tsunami in Canterbury is generally seen as very small but the consequences are potentially catastrophic (Owens et al.,1994).

1.2.4. TSUNAMI RISK INFORMATION IN CANTERBURY

It is important to elaborate on the information content, which was available for Canterbury's coastline residents, to understand the influence it may have on their natural warning response and on the indicators used in this paper to explain it. The various amount of non-governmental information, presented through media and/or social interactions can of course not fully be covered, therefore this chapter focuses on information provided by civil defense agencies which are responsible for the respective district.

To illustrate the possible influence non-governmental information sources like newspaper articles can have, one in June 2012 printed article is briefly discussed. This article released by The Press (see Appendix 2) gives the impression that a locally generated tsunami needs around one hour travel time to reach the coastline and claims that the tsunami siren warning system should be reconfigured to warn for such an event (Gorman, 2012). The tsunami sirens warning system was implemented in discussed in detail in Chapter 1.2.4.2 later on.

According to the Environment Canterbury Hazard Analyst H. Grant, this statement is simply wrong and misleading, as the calculation of travel time is based on insufficient consideration of tsunami generation sites (Interview, 2. July 2012). This example is quoted to highlight the variety of hazard information available and illustrates the complex influences which may influence natural warning behavior.

An attempt is now made to cover information provided by civil defense, regarding the risk of a locally generated tsunami. This information varies slightly depending on locality and time. The case study took place in three different districts, with different civil defense councils, which used different public policy methods to inform their residents about the hazard tsunami. In the following chapters, the differing regional tsunami hazard information approaches are summarized, to allow a more specific analysis later on.

The complexity of hazard information available to the people of Canterbury is further enhanced by recent research conducted in response to public concern after the 23rd December 2011 aftershock, with regard to the risk of a locally generated tsunami. This research altered the evacuation information to the public after March 2012, according to the Environment Canterbury Hazard Analyst H. Grant (Interview, 2. July 2012). This recently conducted research, due to the time of appearing, can not influence the results of natural warning response of the 2010/2011 events, but may alter measured variables such as, risk perception, hazard knowledge, hazard information and so on. Following the tsunami risk information for each district is summarized as the information content for the people living in the country is important to understand.

1.2.4.1. WAIMAKARIRI DISTRICT TSUNAMI INFORMATION

When the risk of a locally generated tsunami occurs the Waimakariri District residents are advised to move to higher ground if they feel a strong ground shaking lasting for more than 20 seconds. The evacuation routes in the beach settlements in Waimakariri, are the main roads out of the settlements. Further, it is stated that a damaging local source tsunami is very unlikely, but cannot completely be ruled out (Waimakariri District Council, 2012). According to Emergency Management and Civil Defense Officer B. Wiremu, tsunami specific community information meetings were conducted in 2009 and 2012, as you can see more in detail in Table 2.

Community Tsunami Information Meetings per coastline area for Waimakariri district	Estimated Participant Number
2009 Waikuku Beach Community Meeting	60
2009 Woodenend Beach Community Meeting	60
2009 Pines Beach & Kairaki Beach Community Meeting	70
2012 Waikuku Beach Community Meeting	13
2012 Woodenend Beach Community Meeting	20
2012 Pines Beach & Kairaki Beach Community Meeting	13

Table 2: Waimakariri tsunami community meetings
Source: Wiremu B. (Interview, 14. June 2012).

These meetings were primarily held to inform residents about the hazard tsunami and the differences between distant, regional and locally generated tsunamis. The only change in the years 2009 and 2012 meetings were some alterations in the inundation maps presented, as the earthquakes had impacts on land elevation, river flood banks and riverbed levels. The evacuation advise was presented, consistent with the information displayed at the Waimakariri District Council webpage. Furthermore there are currently no sirens used for the purpose of tsunami warning, but the installation is planned in the local 10 years development plan (Interview, 14. June 2012).

1.2.4.2. CHRISTCHURCH CITY TSUNAMI INFORMATION

The Christchurch City Council states on its homepage that the risk for a locally generated tsunami is very low and has not changed as a result of the earthquakes. Natural warnings, like a strong ground shaking that makes it hard to stand up, a sudden rise or fall in sea level, or a loud and unusual noise from the sea, may be the only warning for a local source tsunami. Further it is highlighted that there is no official warning for a local source tsunami and residents are advised to respond to the natural warning, if they are on the beach, within two blocks of the coast, estuary or a river mouth. Residents are advised to move quickly inland, to higher ground (at least 4 meters), to the upper storey of a multi-storey building, or to the nearest dune. Further it is advised to only use the car if necessary and to consider unstable cliffs and rock fall in hillside suburbs (Christchurch City Council, 2012a).

According to Environment Canterbury Hazard Analyst H. Grant, recent research regarding the threat of a locally generated tsunami, distinguishes in terms of inundation depth of distant and regional source tsunamis. At the time when the Darfield earthquake hit, such a distinction was not made, although it was clearly portrayed to the public that a distant source tsunami is more likely than one from local source. The evacuation message to move inland or to higher ground was mediated to the public, whereby specific details regarding the travel distance (two blocks inland) were not mentioned, because of missing research prior to March 2012(Interview, 2. July 2012).

At the city councils website a tsunami evacuation information folder (see Appendix 1) informs residents about the evacuation zones, however they might not be accurate any more due above discussed information changes for local-source tsunamis. As Appendix 1 shows, the information regarding a local tsunami is that the risk is considered low, however the tsunami could reach within minutes. If people feel an earthquake lasting more than several seconds, and have difficulty standing or walking, they are advised to move well beyond the evacuation area, to high ground immediately, or to a higher level in a multi-storey building, if travel time is limited (Christchurch City Council, 2012a).

A further important aspect of tsunami related information in the Christchurch City District is the installation and testing of a tsunami siren warning system along Christchurch's coastal area (Christchurch City Council, 2012a). According to Christchurch's civil defense and emergency manager M. Sinclair, the process of the establishment of 22 sirens in 2012 was accompanied with public information campaigns like leaflet drops (see Appendix 3), radio shows, specific website information, media releases, community meetings and road signs at high frequented streets as shown in Figure 6. The sirens reach from

Figure 6: Tsunami siren testing signes in Christchurch City district

Sumner along the coast line to North New Brighton, however further north, the regions Spencerville and Brooklands are not included in the installation area. The resolution to install these sirens was made in July 2010 with the initial plan to build them within a year, but due to the earthquakes in 2010/11 the installation was postponed until May 2012 (Interview, 19. July 2012). The final test for the tsunami sirens was realized on the 22nd of July 2012 and since then this new warning system is in place (Christchurch City Council, 2012a).

As you can see in Table 3, there were 5 community meetings held in order to inform coastline residents about the hazard tsunami and the purpose of the tsunami warning sirens, whereby the specific information regarding locally generated tsunamis was provided from L. Graham from GNS Science.

Community Tsunami Information Meetings per coastline area for Christchurch City district	**Estimated Participant Number**
9th May 2012 South New Brighton Community Meeting	220
10th May 2012 North Beach 1st Community Meeting	150
10th May 2012 North Beach 2nd Community Meeting	90
14th May 2012 Red Cliffs Community Meeting	75
14th May 2012 Sumner Community Meeting	110

Table 3: Christchurch City tsunami community meetings
Source: Sinclair M.(Interview, 19. July 2012)

An extract from the Red Cliffs community meeting regarding local generated tsunamis, is quoted to demonstrate exemplarily the content of these meetings:

"The tsunami danger zone is within 2 blocks (this is about 400 meter) from the beach, estuary or river or lower than 4 meters altitude. In general the risk for a local generated tsunami is very very low, but if you feel any natural warning signs such as a 'strong earthquake' or a 'rolling earthquake lasting for longer than a minute', and you feel uncomfortable staying at home, please evacuate to higher ground, inland or in the second floor of a house. Current research shows that it is very unlikely that a local tsunami can be generated by any of the faults existing in the cost of Canterbury. If any distant source tsunami should be generated you will receive an official tsunami warning and have enough time to evacuate. Please note that the tsunami sirens, which are going to be installed in June, would alarm you just for a distant source tsunami, in all other cases your natural warnings, like a strong earthquake or a rolling earthquake will be your only warning. In such cases it is your own responsibility to evacuate" (Red Cliffs Community Meeting, 14. May 2012).

Particular for the region Southshore and South New Brighton, a further official source of tsunami information is the Community Resilience Project, which was carried out in 2009 and 2010. The purpose of this project was to identify key groups in the community and inform them about the risk and evacuation procedures in the case of a tsunami. According to M. Sinclair, the information content provided in 5 workshops with around 70 residents participating, is consistent with the general information stated at the beginning of this chapter(Interview, 19. July 2012).

1.2.4.3. ASHBURTON DISTRICT TSUNAMI INFORMATION

The Ashburton District Council website (2012a) states that tsunamis are expected to have a maximum wave height of up to 4 meters and are a threat along Ashburton's coastline, in particular to the river mouth settlement areas. According to an interview with D. Geddes, who is in charge of civil defense in the district, the information at the website and the 'Get Ready Get Through' information brochure are the main sources of information for Ashburton's coastline residents. This brochure contains specific hazard related information, published by the Ashburton Civil Defense District Council and includes detailed information about tsunamis, household emergency plans and get-away kits. For local source tsunamis, it is specifically stated that a tsunami could arrive in minutes and that there will not be time for an official warning. Therefore, it is recommended to move immediately to high ground or inland, if people feel a strong earthquake that makes it hard to stand up, or a rolling earthquake that lasts a minute or more, see a sudden rise of fall in sea level, or hear loud and unusual noises from the sea (Interview, 13. June 2012).

The next chapter focuses on the methodological approach used to gather and analyze data for the proposed study design.

2. METHODOLOGY

As mentioned above, the case studies main aim is to identify socially vulnerable demographic groups in the 'warning' phase of the disaster risk management cycle. Additionally, the natural warning behavior model (NWBM) is used to analyze intra and inter-personal natural warning response model. Moreover, possible temporal changes of natural warning behavior are attempted to analyze, with the use of aftershock behavior, compared to the behavior people showed at the Darfield earthquake. To gather data for the analyze of the suggested models, a survey was conducted which used the style of a personally administered questionnaire, as it is a well-established tool for behavioral response (Bird, 2009). To test structural and measurement relations simultaneously (Kline, 2011) two models were tested with confirmatory factor analysis and structural regression modeling, with the statistical package AMOS v. 20. Path analysis was not chosen, as it is assumed that the indicators in the hypothesized models are latent on the natural behavior response, and vice versa. A further reason is that variables, when testing a causal model through path analysis, should be measured without intercorrelation on each other and they should be unidirectional (no incorporation of feedback loops among variables) (Schreiber et al., 2006). Both assumptions seemed not to be likely in this case study design. The methodology used, allowed the testing of hypotheses regarding effect priority, whereby these effects can involve latent variables with the incorporation of a multiple-indicator measurement model (Kline, 2011). As a data gathering method, a survey was conducted in the form of a personally administered questionnaire, to collect the necessary data.

2.1. DATA GATHERING METHOD: SURVEY

One of the main obstacles to overcome was to find a data gathering method which leads to an efficient number of respondents in the 13 chosen coastal areas. This was practical hard to accomplish due to limited availability of respondents in the areas, and elapsed time between the earthquakes and the time people were approached. It was not possible to generate a contenting sample frame of the residents living in the study sites, as the available dwelling and household estimates do currently not consider the Canterbury earthquake influences (Statistics NZ, 2012a).

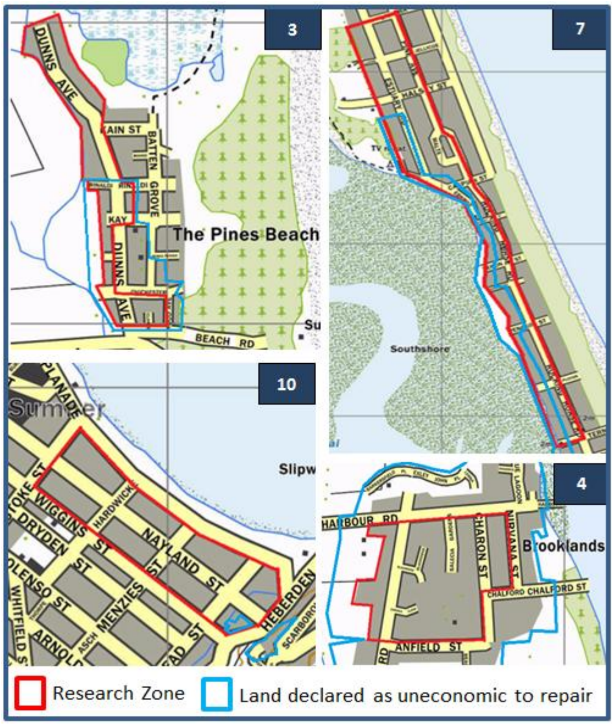


Figure 7: Land use change following earthquakes in four research sites
Source: altered from Freshmap (2012), CERA (2012)

An additional obstacle to generated a sample frame for the study sites, was generated by changes in land use planning at district level, since the earthquakes. Figure 7 shows 4 of the 13 study sites, which have been subject to severe changes in land use planning, forcing residents in affected areas to move within a given timeframe(CERA, 2012).

This development makes the net dwelling and/or household number unknown (Statistics NZ, 2012a) at the point of survey conduction, which implies for this study, that a survey based on a sampling frame was not realizable. To ensure the random selection of participants, a personally administered questionnaire was used, to gather the necessary data for the proposed indicators. To overcome the obstacle of having no exact data for the number estimation of people in the study sites, the inhabited houses were counted one week prior to the start of the questionnaire conduction. Per 50 houses 4.5 approaching hours were assigned, which led to a total of 130.5 hours participants approaching time in 8 weeks of June/July 2012. Each study site had to be approached at least on one weekday, Saturday, and Sunday, to ensure that participants employment status is not critical for their selection. The daytime and geographical starting point of approaching was selected randomly using a dice.

Appendix 4 shows a detailed description of the approaching hours and correlated participant numbers per study site.

A personally administered questionnaire was used, because of its advantages, that each respondent was asked the questions in exactly the same way, to ensure that each questionnaire was completely fulfilled, and because of the inability of the respondents to bias in their initial responses(Frazer & Lawley, 2000). The latter advantage is important for the study design, as the questionnaire evaluated knowledge and other sensible data, which had to be gathered under certain conditions (e.g. no presents of others). Furthermore a questionnaire is a common and well-established tool for behavioral response, attitudes, and beliefs in research (Bird, 2009).The full questionnaire and the questionnaire analysis sheet, are enclosed as Appendix 5 and 6. Participants had to fulfill a screening process in order to be eligible to participate. Respondents had to be:

- located within the defined study site area (on the ground floor) on the 4th of September 2010 at 4.35am,
- at least 18 years old,
- capable of knowing sufficiently English in order to understand and answer the questions, and
- not distressed regarding questions about the past earthquakes and had to be prevalent before or during the interview.

Those who met the screening criteria and who agreed to participate (please see Recruitment Script, Appendix 7), were asked to answer the questions in the questionnaire, which took in average 13.5 minutes. Prior to the actual conduction of the questionnaire, a pre-test was conducted to allow the assessment of the time for questionnaire conduction, to test the data analyze techniques, as well as the check of the properties of the data collection itself. Besides idem reasons for choosing the tool of a personally administered questionnaire, this style allowed the use of more complicated skip patterns, show cards (see Appendix 8) and the wording to be standardized so that all respondents were asked questions in exactly the same manner throughout the whole data gathering process (Frazer & Lawley, 2000), which made the results more robust.

2.2. DATA ANALYSATION METHOD

The data gathered with the survey is entered in the statistical analysis package SPSS v. 20, and the hypothesized relationships are analyzed using the structural equation modeling (SEM) program AMOS v. 20. The assumptions of multivariate normality and linearity were evaluated with SPSS. SPSS is further used to test relationships in between some of the variables, for the general analysis of natural warning response over time, and for the natural warning perception specifics. As the hypothetical constructs are not directly observable (latent), the only way is to use observed scores for an indirect measurement (Kline, 2011). This observed scores are the proposed indicators for the models, illustrated in the form of a square shape, whereby the latent ones use an oval shape. The circles at the side of each factor are the displayed 'measurement errors' in the variables, where the straight line pointing from the latent variables to indicators indicates the causal effect of the latent variable on the observed variables (Schreiber et al., 2006). The model is theory driven and analysis the theoretical relationships among the observed (indicators) and unobserved/latent variables. The graphic representations show the hypothesized model in order to test it, to see how well it fits the observed data. After initial model fit testing, post hoc tests were conducted in order to eliminate model fit issues and generate better model fit. This part is for each hypothesized model, elaborated explicitly in the relevant chapters in the results section. In the next two subchapters, the proposed models are illustrated and their data input for the indicators are described.

2.2.1. NATURAL WARNING RESPONSE DEMOGRAPHIC INDICATOR MODEL

Figure 8 shows, the demographic indicators used in the model for the demographic indicator identification. The observed demographic variables, generate a latent variable termed 'demographic influenced natural warning response', using residents actual behavior, shown after the Darfield earthquake. The demographic used indicators, relevant scaling, and question number in the questionnaire for the model is shown in Table 4, whereby the concrete group levels used can be found in the questionnaire analysis is sheet in Appendix 6. It should be mentioned specifically that the indicator 'Nationality' is categorized as low or high country tsunami frequency, the details for this categorization can be found in Appendix 7.

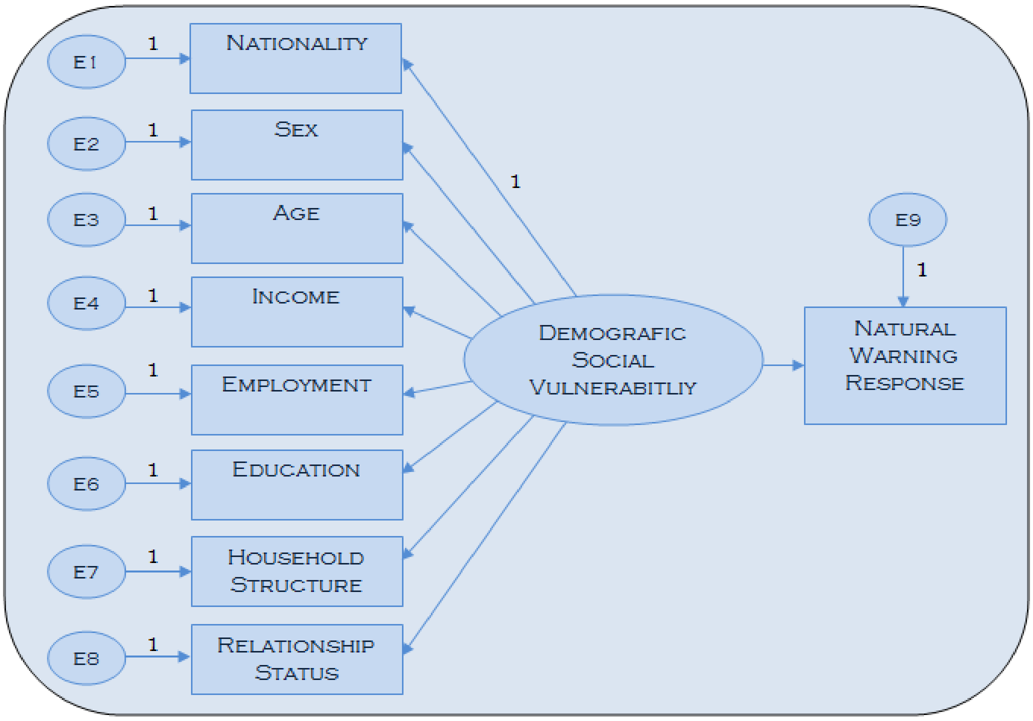


Figure 8: Demographic natural warning response model for AMOS

Demographic Indicator	Scale	Question No.
Sex	male/female	28
Age	1 (low) - 18 (high)	30
Income	1 (low) – 12 (high)	31
Employment	1 (low) – 3 (high)	32
Education	1 (low) – 5 (high)	33
Relationship	1 (low) – 3 (high)	34
Household Structure	1 (low) – 3 (high)	35
Nationality	1 (low) – 2 (high)	21

Table 4: Demographic indicator scales with associated question numbers

The crucial indicator 'Natural Warning Response', which determines respondents social vulnerability for the warning phase, is gathered with Question No. 6 and reflects respondents actual behavior in response to the natural warning generated by the Darfield earthquake.

2.2.2. NATURAL WARNING RESPONSE MODEL FOR INTRA- & INTER PERSONAL INDICATORS

Figure 9 illustrates the hypothesized model which is conceptualized following the theoretical approach introduced in Chapter 1.1.7.

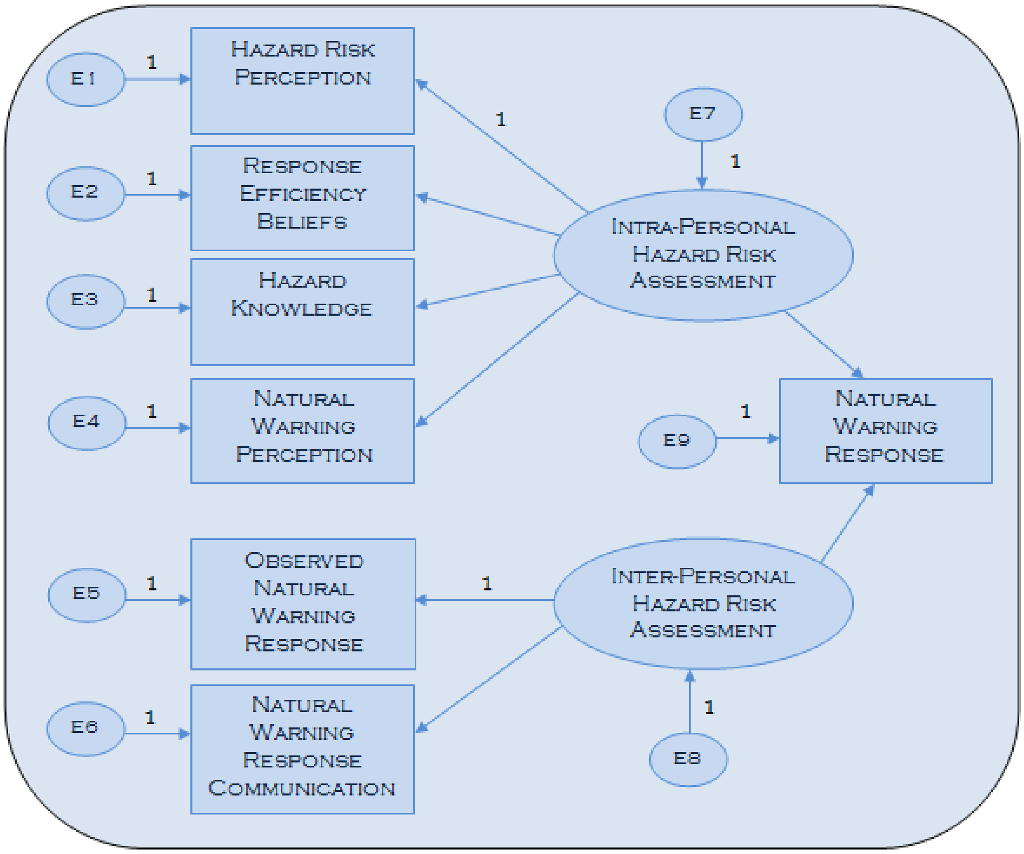


Figure 9: Natural warning response model for intra- & inter personal indicators for AMOS

For both hypothesized models the factor 'Natural Warning Response' is gathered the same way using question 6. Other observed variables for the model are gathered and measured using the following concepts.

2.2.2.1. HAZARD RISK PERCEPTION

As mentioned earlier on, the concept of building risk perception is a very complex process (Slovic, 2000) hence it is impossible to gather all influencing parameters. For the purpose of this research, the tsunami risk perception of respondents is measured with the three influencing parameters:

- personal estimated likelihood of a damaging tsunami occurring in living area (Q.13; Option 1-3 High, 4-8 Low); (Hazard Risk Perception 1),
- personal consternation, regarding a tsunami in the future (Q.14; 1 High, 2 Low); (Hazard Risk Perception 2), and

- level of perceived safety regarding the risk of a tsunami (Q.16; ≤ 50% Low, >50% High); (Hazard Risk Perception 3).

Each input variable is scaled in low or high to allow the overall determination of a low or high hazard risk perception. To get an estimate to set the mean for scaling the likelihood of tsunami risk, this study defines that a wave height of 4 meters above mean sea level can be seen as the cause of a damaging tsunami. As the return period for such an event in Canterbury is 500 years (Berryman, 2005), respondents who ticked option 1 to 3 are considered to have a low estimated hazard likelihood estimation, whereby answer option 5 to 8 are scaled as high. Missing data from one variable is replaced by the data gathered from other components of the factor hazard risk perception.

2.2.2.2. HAZARD KNOWLEDGE

The estimation of hazard knowledge in this case study refers to the hazard tsunami. To measure this, this research focused on the specific knowledge, relevant for hazard response and warning. Therefore respondents knowledge regarding the arrival time of a tsunami was chosen in order to represent this factor(Q.18; 1=positive,2=negative). For the event of a local generated tsunami, the information regarding the evacuation time is crucial within the evacuation behavior, as it determines the survival from a tsunami. The tsunami information provided to people in New Zealand regarding 'tsunami arrival time' is defined inconclusively and dependent on the definition given by the emergency management agency in the respective district (compare Chapter 1.2.4.). Therefore, this factor uses the highest suggested arrival time, which includes all other sources and scales the respondents' estimated arrival time 'less than 5 minutes' as right, hence the respondents who knew that, are associated with a positive hazard knowledge.

2.2.2.3. RESPONSE EFFICENCY BELIEF

Response efficiency beliefs are measured with the level of perceived control of a respondent in order to respond with personal actions to the potential tsunami, to increase survival chances (Q.15). A respondents' belief is categorized as high, if the perceived control in order to respond to the hazard, is higher than 50%. The construct of 'Outcome Expectancy' is a factor that measures peoples beliefs about the efficacy of protective actions (Paton, 2008). In this sense, negative outcome expectancy reflects the beliefs that the consequences of a tsunami are too disastrous for personal action to make any difference to people's safety. To analyze this factor, question 15 is raised to the respondents with the visual bar as the answer tool. Paton et al. (2008) states that if people have a negative outcome expectancy, no further action regarding preparation is likely. The same might also be true for natural warning response, which is why this indicator is included in the hypothesized NWRM.

2.2.2.4. NATURAL WARNING PERCEPTION

The perceived duration and intensity of the Darfield earthquake serves as the variables composing the factor Natural Warning Perception (Q.2, Q.3; negative=1, positive=2). People who perceive natural warning signs in the form of a long and/or strong earthquake are advised to move to higher ground. As Table 5 illustrates, the definition of 'long' and 'strong' is not consistent in the districts, therefore this factor is calculated per district. The differing criteria are used to define respondents warning perception, whereby the term 'several seconds' is set equal with 20 seconds for the purpose of this case study.

District	Perceived Earthquake		Variables	
	Duration	Intensity	single	combined
Waimakariri	20 seconds	strong		X
Christchurch City Council	Several seconds	hard to stand up or walk steady		X
Ashburton	more than a minute	Hard to stand up	X	

Table 5: Earthquake experience criteria for natural warning indication

The earthquake perceived as strong without a specific definition, could lead to the allocation as Modified Mercalli Intensity Scale 6, which is defined as "Walking steady is difficult" and is therefore one scale under Mercalli Scale 7 which is defined as "People experience difficulty standing" (see Appendix 9). For this variable the stronger predictor is chosen, whereby a positive natural warning is regarded, if the respondent had difficulties to stand up. People experiencing difficulty standing up would consequently find it hard to walk steady, and are consequently associated with positive experienced quake intensity.

2.2.2.5. NATURAL WARNING RESPONSE COMMUNICATION

In the hypothesized model, natural warning communication is included for influence estimation on the inter-personal assessed hazard risk, which may influence respondents natural warning response. The inclusion of the this indicator is essential, because when people face an unfamiliar risk, they tend to ask others, who share the same interests and values, to help them to reduce uncertainty and help them to manage their risk more appropriate (Lion et al., 2002). To gather the data for the indicator, the existence of communication during or after the Darfield earthquake, in terms of possible evacuation, is regarded as the factor 'Natural Warning Response Communication' (Q.8; negative=1, positive=2). The question 8.1 analyses the relationship of persons with whom the respondent communicates with, as Paton (2008) states that mostly family and community members are used to gather information regarding the state of hazard preparation.

2.2.2.6. OBSERVED NATURAL WARNING RESPONSE

This factor analyses how a respondent perceived the natural warning response of others in terms of evacuation, when the Darfield earthquake struck. If the respondent behaved likewise the majority of the people he/she saw, the factor social behavior is regarded as positive (Q.6/Q.7; 1=positive, 2=negative).

2.2.3. ADDITIONAL GATHERED VARIABLES

A comprehensive view on gathered variables and their intended use, can be found in the questionnaire analyze sheet in showed Appendix 6. Not every collected data was used for analyze, mostly because of low 'n' or other reasons, elaborated later on. In this chapter the variables which need to be explored in detail for the following discussion and analysis, are discussed in more detail:

For the evaluation of observed and carried out natural warning behavior change over time, respondents presence in the according study site is a prerequisite to compare behavior changes over time(Q.9).

To gather data for this comparison:

- natural warning response (Q.9.4),
- observed natural warning response(Q.9.4/9.5; 1=positive, 2=negative),
- intended future natural warning response (Q. 10/10.1; no evacuation=1, evacuation=2), and
- natural warning perception (Q.9.2, Q.9.3; negative=1, positive=2) are used.

As for the aftershocks, a felt earthquake intensity map (as Figure 5 for the Darfield earthquake represents) is not available. This analysis was only able to be conducted for the part of the population who experienced the earthquake and aftershock as natural warning (following the criteria given in the relevant district). This approach has certain limitations, as will be discussed later on, but allows basic conclusions to be drawn about behavior changes.

To allow practical implementations of this research for the study regions, regarding the recently implemented tsunami sirens warning system, the respondents knowledge about the warning principle is gathered. Two questions measure the respondents' ability to distinguish between local and distant source tsunami in regards to tsunami warning (Q.11/11.1; positive=1, negative=2). For this purpose, the study sites are segmented according to their use of sirens for the purpose of tsunami warning in:

- Area 1 with no sirens for the purpose of tsunami warning at all,
- Area 2 which recently got sirens installed for the purpose of tsunami warning only, and
- Area 3 which use the fire sirens for the purpose of tsunami warning.

Further on, the factor religiosity is gathered with the use of a visual scaling bar(Q.29), to allow an analysis of a potential relationship between the level of self estimated religiosity and natural warning response.

Event Preparedness is a composite factor, consisting of having a survival kit and a household emergency plan. Both are suggested to have, when preparing for an emergency by the civil defense authorities in Canterbury (ECAN, 2007), and are measured and controlled in the questionnaire (Q.19/19.1/20/20.1).

Visual scales were additionally used to measure the level of trust towards governmental abilities to cope with disasters (Q.26) and how reliable the respondents considered the tsunami information provided by governmental agencies to be (Q.27).

The level of event preparedness is measured with questions regarding the existence of personally administered preparation actions (Q.19/19.1/20/20.1), which are used, not exclusively, to mitigate tsunami risk.

Additionally, data regarding respondents self estimation of tsunami preparedness is gathered (Q.17), for a possible comparison of actual hazard knowledge and hazard knowledge self estimation(see Q.25).

3. RESULTS

In the 130.5 hours 609 people were selected randomly and approached in the selected study sites. Out of the 609 people, 127 agreed to participate and fulfilled the screening criteria to be eligible for participation. One questionnaire was not useable, as more than 50 per cent of the questions were not answered the volume of missing data was regarded as too high for analysis purposes. This led to a total sample size of 126 respondents. For structural equation modeling, this sample size is important, as the likelihood of technical problems or statistical estimates, such as standard errors, may not be accurate when the sample is to small (Kline, 2011). There is no exact rule for the number of participants (n) needed (Schreiber et al., 2006), which leads to a varying participant per factor ratio in literature (Tanka, 1987; Bentler & Cou, 1987; Jackson, 2003). A recently revised article positions that n = 20 is unrealistically high and several published studies do not meet this goal (Kenny, 2012), whereby Schreiber et al. (2006) mention that n = 10 appears to be the general consensus, Bentler & Chou (1987) state that a minimum sample size ratio of n = 5 per factor is sufficient. However, for the two hypothesized models a respondents-factor-ratio of 5.25 (demographic SVI), and 5.73 (psychological-cognitive SVI) was achieved, for the original models. For both models the variables missing data was analyzed by visual inspection of patterns and was deductive defined as random, which allowed missing data to be imputed by expectation-maximization algorithm with SPSS v. 20. For both hypothesized models maximum likelihood parameter estimation is chosen over other estimation methods, as the data sets were distributed normally (Kline, 2011). Detailed model fit data and conducted post-hoc modifications are shown in the regarding chapter. Natural warning response changes over time and natural warning perception during and/or after the Darfield earthquake, are identified in relevant chapters.

3.1. SINGLE VARIABLE RESULTS

Nearly every respondent (98.1%) reported his or her native nationality in a country with low tsunami occurrence , which led to a very low variance [v=0.13]. Figure 10 shows the respondents age groups (98.2% answered) with the mean age located in the group 61 to 65 [sd=3.12]. The variable Relationship Status, is categorized in 3 groups and has its mean in the group 'living with partner' [m=2.29, sd=0.90]. As Figure 11 illustrates, 46.03% of the respondents stated that they live in 'households together with others', followed by 34.13% living in 'households with children' and 19.84% living in single households.

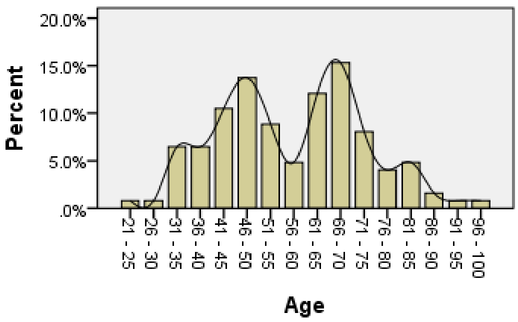


Figure 10: Age group distribution

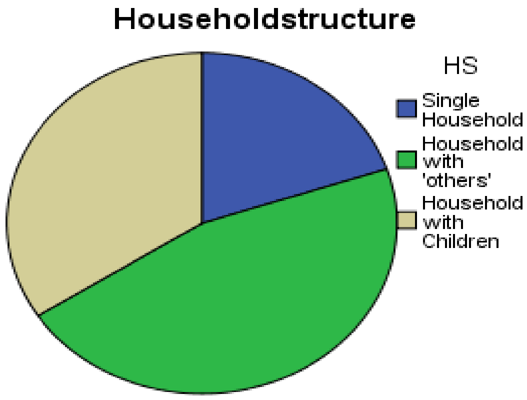


Figure 11: Household structure

There are no missing data for the variables Nationality, Sex, Relationship Status, Employment Status, and Household Structure. Male respondents represent the bare majority of the sample with a percentage of 54.8. The income group is quoted by 96% of respondents and has its mean located in the category of NZ$ 40.001,-- to NZ$ 50.000,-- [sd=8.55], whereby people earning between NZ$ 70.001,-- to NZ$ 100.000,-- represented and the biggest group [19%]. As the frequency tables for education and employment displayed in Table 6 and 7 illustrate, most respondents completed or achieved either trade, polytechnic or diploma level (38.4%), and 19.2 percent hold a higher education than this average group. In terms of employment status, the sample is split into the biggest group 'unemployed with 46%, followed by 39.7% beeing full-time or self-employed and the smalest group with a part-time employment of 14.3% [m=1.94, sd=.93]. The varibales (HRP 1, HRP 2, HRP 3) used to represent the indicator hazard risk perception have a low average percentage rate of 6.1% missing data [HRP1 = 14.3%, HRP2 = 4%,HRP3 = 0 %].

Education

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	'did not complete High school'	14	11.1	11.2	11.2
	'completed High school'	39	31.0	31.2	42.4
	'completed/achieved trade, polytechnic, diploma'	48	38.1	38.4	80.8
	Completed undergraduate, bachelors degree	15	11.9	12.0	92.8
	Postgraduate, honors, masters, doctorate degree	9	7.1	7.2	100.0
	Total	125	99.2	100.0	
Missing	System	1	.8		
Total		126	100.0		

Table 6: Education groups frequency table

Employment

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	'unemployed'	58	46.0	46.0	46.0
	'part-time employed'	18	14.3	14.3	60.3
	'full-time or/and self-employed'	50	39.7	39.7	100.0
	Total	126	100.0	100.0	

Table 7: Employment groups frequency table

Almost half (49.1%) of the respondents estimated the likelihood of a damaging tsunami (HRP1) between 10 and 499 years [m=3.79, sd=2.29], whereby the majority of the total respondents [57.9%] think that they will be effected by a tsunami in the future(HRP2). The mean level of perceived safety expressed in percentage, regarding the risk of a tsunami (HRP3) is 63.76 [sd=30.1].

In total 75.8% of the 120 participants who were able to recall their neighbors behavior, responded the same way as they did at the time of the Darfield earthquake. This number is even higher at the time of the aftershocks, where 97.8% of the 97 respondents who answered the question, responded the same way as their neighbors. In total 22.2% of the respondents showed a basic understanding of the warning principle of tsunami sirens. This number gained in 13 study sites, split in areas according to their use of the warning system(compare Chapter 2.2.3) shows that no significant difference between these areas [$\chi^2(2.126)=5.02$, *n.s.*]. Whereby 21.1%

in Area 1, 27% in Area 2, and 0% in Area 3 of the respondents showed an understanding of this warning principle. Respondents having trust in hazard information, provided by the government, has a mean of 49.63[sd=26.77], whereby the trust in the governmental abilities to cope with a disaster of any kind is slightly lower, with its mean at 46.16 [sd=28.09]. The majority of respondents estimated their knowledge about the hazard tsunami with less than 50% [m=45.03, sd=22.59]. A t-test indicated that there is no reliable relationship between natural warning response and level of religiosity [t(123) = 1.36, *n.s.*]. Another t-test, used to examine the relationship between warning perception and age, suggested that there is a reliable relationship between these two variables [t(117)=2.04, p<.05]. The respondents efficency beliefs regarding personal taken counteractions twards the hazard tusnami, has a mean of 64.44 (sd=30.95). A two-way ANOVA was conducted to test whether hazard preparedness and natural warning response were related to HRP3. This analysis indicated that there was significant main effect of hazard preparedness [F(2,104)=3.17, p<.05], but that neither the main effect of natural warning response or the interaction between hazard preparedness and natural warning response were significant [F(1,104)=.01; F(2,104)=.40, respectively].

3.2. DEMOGRAPHIC NATURAL WARNING RESPONSE MODEL

When examining the original hypothesized model the p-value of 0.001 indicates together with the RMSEA higher than 0.1 poor model fit. Post hoc modification indices showed that the covariance of the variable Relationship caused the highest model fit issues (with Household Structure [M.I.=15.8], and Age [M.I.=7.4]), which lead to the decision to remove this variable.

Model Fit Parameters	Normed Fit Index (NFI)	Tucker-Lewis Fit Index (TLI)	Comparative Fit Index (CFI)	Root mean square error of approximation (RMSEA)	CMIN/DF	P
Original Model	0.749	0.762	0.830	0.104	2.358	0.001
1st modification	0.849	0.896	0.931	0.073	1.658	0.057
2nd modification	0.936	1.001	1.000	0.000	0.989	0.446

Table 8: Model fit summary for demographic natural warning response model

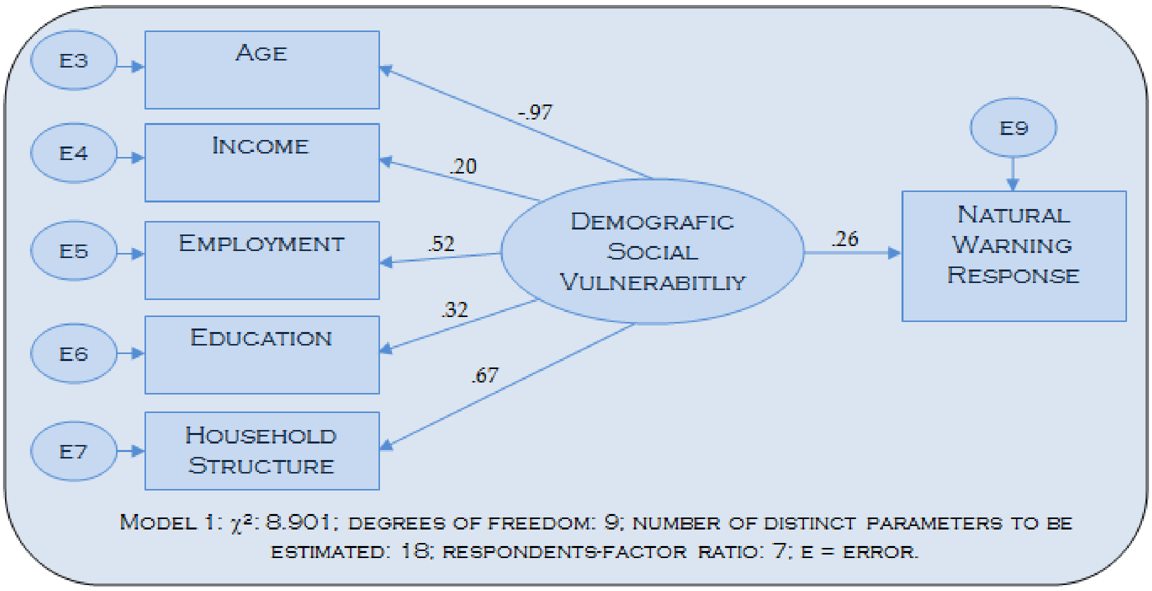


Figure 12: Demographic social vulnerability indicators model with standardized regression weights

As Table 8 shows this model modification improved all fit indexes, whereby NFI, TLI and CFI are still under the threshold of 0.95 for acceptance (Schreiber et al., 2006). Therefore a second modification indices inspection identified the variables Sex and Employment [M.I.=10.76] as model fit issues, which lead to the drop of the variable Sex, as it had a lower correlation (0.03) to the latent variable. This second modification lead to a substantially improved model fit, with TLI and CFI over the recommended threshold and the NFI just below it. The model after modifications is shown in Figure 13 and illustrates the standardized parameter estimates. The model fit parameters now indicate a good fit between the model and the observed data. The variables, Age, Household Structure and Employment have the highest standardized parameter estimates, whereby Age shows a very high (-.97) negative correlation.

3.3. INTRA -& INTER PERSONAL NATURAL WARNING RESPONSE MODEL

As Table 9 illustrates, the model fit indexes and the p-value of 0.016 indicates a poor model fit, although the RMSEA is lower than 0.1.

Model Fit Parameters	Normed Fit Index (NFI)	Tucker-Lewis Fit Index (TLI)	Comparative Fit Index (CFI)	Root mean square error of approximation (RMSEA)	CMIN/DF	P
Original Model	0.817	0.825	0.892	0.090	2.017	0.016
1st modification	0.892	0.903	0.948	0.077	1.733	0.085

Table 9: Model fit summary for intra- & inter personal natural warning response model

A conducted post hoc analyze indicated model fit issues, which led to the following modification. The high regression weights between the observed variable Hazard Knowledge, with the latent variable, Intra Personal Risk Assessment [M.I.=6.820] lead to the drop of the variable Hazard Knowledge. The modification altered the p-value above 0.05 and all model fit indices indicate better model fit, whereby only CFI is very close to the 0.95 threshold of acceptance (Schreiber et al., 2006). An additional conducted modification indices analysis showed no improvable covariance issues, which led to no further modification. The model after the first modification is shown in Figure 14 and illustrates the standardized regression weights between variables.

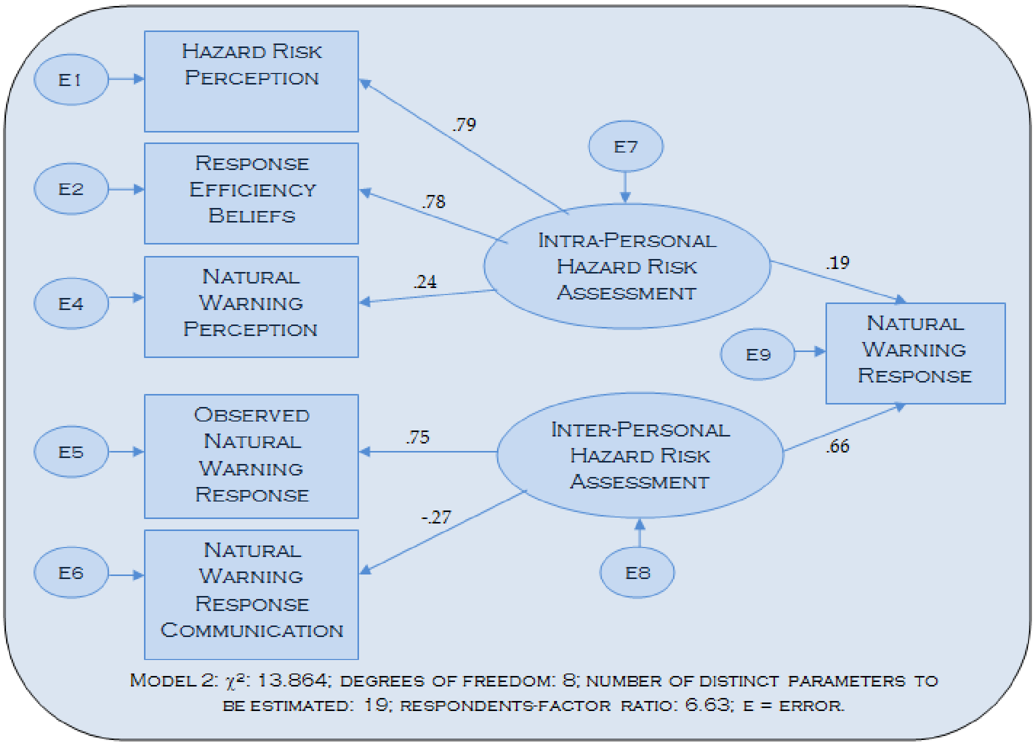


Figure 13: Intra- & inter personal natural warning response model with standardized regression weights

3.4. NATURAL WARNING PERCEPTION, RESPONSE AND FURTURE INTENSIONS

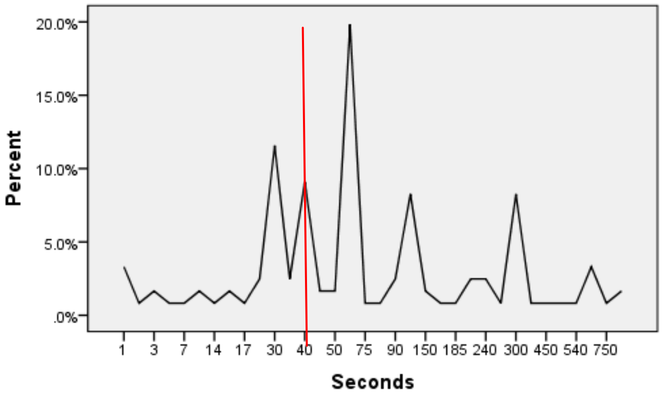


Figure 14: Percieved earthquake duration: Darfield earthquake 4th Sept. 2010

A total of 121 people answered the questions to estimate the factor 'natural warning perception', whereby 78.5% of the respondents perceived the Darfield quake as a natural warning (for criteria see Chapter 2.2.2.4). The Darfield earthquake duration was estimated by 124 respondents, with 82.3% describing the felt intensity as 'hard to stand up'. The duration of the Darfield earthquake is estimated by 121 respondents, illustrated in Figure 12 and has a mean duration time of circa two and a halt minutes [m=151.25; sd=263.12], whereby the actual duration is indicated by the red line at the 40 seconds mark.

The perceived aftershock intensity and duration was quoted by 95 respondents, whereby about half of them (51.6%) perceived the respectively aftershock as positive natural warning. Note that this data does not reflect one specific aftershock, but one of the three major ones.

A total of 38 respondents perceived both (Darfield earthquake and one aftershock) as natural a warning. One respondent could not recall the behavior following the aftershock, which leads to a total of n = 37 for the analyze of natural warning behavior over time following a perceived natural warning: Out of these 37 respondents, 18.4% went to another place in order to evacuate from a possible tsunami when the first earthquake struck. The warning response during the Darfield quake, compared with the future behavior intensions, shows a significant difference ($\chi 2(1.37)=6.98$, $p=.008$). 10.8% of the respondents who evacuated after the Darfield earthquake still intend to evacuate in the future, if a similar earthquake would hit. About one third (66.7%) of the respondents who evacuated during the Darfield quake mentioned that they intend to do so in future. Out of the total 37 respondents with positive natural warning experience in both earthquakes 75.7% reported that they do not intend to evacuate, in the case of a future event.

The behavior in terms of a natural warning response after the Darfield earthquake was stated by 125 respondents and 20.8% of them evacuated due to the potential tsunami.

4. DISCUSSION

The data gathering method was not very efficient due to obstacles faced when approaching respondents in the research sites (roughly 1 respondent per hour), however insured people to be selected under random conditions, which increased the robustness of the sample. Although a larger sample size would have been preferred to test additional hypotheses related to social vulnerability, with the use of variables such as, hazard experience, self estimated hazard preparedness, and actual preparedness, the sample size is sufficient to test the hypothesized models. The personally conducted interviews ensured that respondents were eligible and the questionnaires were completed fully by each respondent. However 1 questionnaire had to be dropped, because more than 50% of the data was missing (caused by the lack of memory of the respondent). Open-ended questions would have been interesting to include, in order to gather more detailed data, applying this style of questioning was not possible due to time constraints. Further, some indicators would have preferably been estimated with more questions, however as the questioning time was limited to a maximum of 15 minutes, initially included questions had to be dropped.

The case study design faces some obstacles due to current practices in the relevant emergency management agencies in the districts, as these are responsible for hazard education in New Zealand. For example, the incoherence regarding the natural warning trigger definition (time & intensity), created complexity in the natural warning experience definition discussed earlier on. It is imaginable that these differing data may also cause problems for the people in Canterbury, to identify natural warnings appropriately. Further, the alteration of hazard information after the December 2011 aftershock, and some area specific public education campaigns, generated a certain degree of complexity and difficulties for some variable assessments and its validity. This is an additional reason why some initially planned a methods of analysis, could not have been carried out in this case study. Gathered variables however, only represent an estimation of a certain moment in time and might be easy influence able (see the example of the newspaper article, or tsunami sirens implementation) by unforeseen factors., therefore the data of this survey has to be examined, with this knowledge in mind.

4.1. SAMPLE DESCRIPTION

The nationalities represented in the sample do not necessarily represent the ethnic group distribution of the total population in New Zealand. Certainly, the ethnic groups Māori, Asian and Pacific People are underrepresented, as they are hardly present in the sample size, compared to the national New Zealand statistics (Statistic NZ, 2012b). This may be caused by the lack of presence of these ethnic groups at the study sites as there is no detailed ethnic group distribution for the study sites available. However, the source of the missing ethnic distribution in the sample can not be determined. The age average located in the group 61 to 65 is higher, as the age average of the study sites of 37.6 years (see Appendix 10). This may be influenced by the fact that some study sites are retirement and holiday villages (Interview D. Geddes, 13 June 2012). Further it was observed that younger respondents approached, were more likely to not participate as respondents than the elderly (for general approach/respondent ratio see Appendix 4). This might influence the results in terms of overrepresentation of the elder population. The income national average is lower at NZ$ 24.400,-- annually(Statistic NZ, 2012b), than the average group. This might too be related to research conduction in the study sites as it could be possible that holliday home owners might have in general, a higher income, than those approached in common settlement areas. Additionally, there is a relatively high representative group of unemployment compared to the national average (Statistic NZ, 2012b), which is probably too explainable with the average age. The drop of the variables Mobility and Nationality, because of low variance, lead to the exclusion of these indicators from the analysis, which failed to allow a comprehensive analyzis with the testing of all initially included indicators.

In general, it can be stated that the survey obtained a higher age, imcome and unemployment group than the national average. The reason for this might be due to the study site characteristics, or perhaps also derive from other unanticipated sources. At this stage, the reason for this cannot be determined, which suggests that the data of this variables has to be treated with care.

4.2. SOCIAL VULERNABILITY INDICATORS

The two models had a sufficient respondent-factor ratio, due to Bentler & Chou (1987), which allowed testing for model fit and identifying possible indicators. The required sample size for model analysis shows a respondents-factor-ratio of higher then 5, which is regarded as sufficient (Bentler & Chou, 1987) and enabled adequate testing. The model for identifying demographic variables as indicators for social vulnerability, showed after model fit substantial improvement, which led to very good model fit indices. However, as Figure 13 shows the degree to which the demographic variables are associated with natural warning response is not very high, which questions the validity of the high standardized parameter estimates of the variables Age, Household Structure and Employment. The results do however allow a ranking of demographic importance for social vulnerability. The model suggests that age is high associated with the actual natural warning response at the 4th of September earthquake. This supports a theory that the older the respondents were, the more unlikely they were to evacuate, and act therefore according to the natural warning. This missing evacuation behavior is not related however, to a missing natural warning perception. Further, the level of self estimated religiosity seemed to have no significant relation to natural warning behavior.

The second strongest demographic indicator is Household Structure, which is split according to the household members status: single household, household with partner or others, and household with children (for details see Questionnaire Analysis Appendix 6). This relatively high standardized regression weight, indicates a trend towards a more likely natural warning response for members of households with the presents of children. However, at this stage it can only be mentioned that there seems to be more correlation than other indicators like, Income, or Education shown. Also the employment rate shows a relatively high correlation, which suggests that employed participants were more likely to evacuate. At this stage it has to be mentioned that all these results may be influenced by the possible overrepresentation of older population groups in the sample, mentioned in the previous chapter. For example, it may be that unemployment is higher in older population groups and the same could be for the household structure (the older the people the more likely it could be to live in a 'low level' household). As these questions cannot be answered conclusively in this paper, the demographic model is not regarded as very predictive for natural warning response.

Also, the second model reached acceptable model fit indices after the first modification. This model suggests that inter-personal variables have higher influence on natural warning response, than intra-personal variables. Interesting is the high standardized estimates of the variable representing observed natural warning response, which indicates that peoples' natural warning response is associated with the response of others. The analysis with SPSS indicate strong support for this in the model identified relationship. Three quarters of the sample, acted the same way as their neighbors after the Darfield earthquake, and 98% did so after one of the major aftershocks. This connection is important as it allows implementations for emergency management at a local level, which will be elaborated later on. The negative standardized regression weight of Natural Warning Communication, suggests that people who communicated directly after the earthquake regarding evacuation, mostly decided to not respond to the natural warning. This result could even indicate that the less people talked about evacuation, the more likely they were to evacuate. However, it is a finding which must be explored further in detail in future behavior research. For the intra-personal hazard risk assessment, the variables hazard risk perception and response efficiency beliefs, seem to be most determining, whereby as mentioned earlier on, the overall validity of intra-personal variables is not very high. In general, it can be stated that demographics do not serve as sufficient indicators when describing social vulnerability.

4.3. NATURAL WARNING RESPONSE CHANGE OVER TIME

About a fifth of the population evacuated after the Darfield earthquake in order to flee from a potential tsunami. The analysis of the behavior at the time when the aftershocks hit, indicates that this rate decreased substantially to only around five percent. Further, three quarters reported that they are not willing to evacuate, if they would experience a similar earthquake again. Unfortunately, the behavior analysis of the aftershocks, faced the obstacle low of participant numbers. For this analysis only data was analyzed from people who experienced both earthquakes as natural warning. This limitation in the case study design was necessary, as it had to be assured that people experienced the aftershock as strong enough to respond to it, as the aftershocks occurred very shallow and geographically spread, and no felt earthquake intensity map was available, like at the Darfield quake. However, the data indicates a decreasing response rate to the natural warning, which could derive from many reasons. One explanation could be that people simply got used to the ground shaking and did not evacuate because of the presumption that the quakes are based inland. Another theory could be that initially people did not know about the probability of a locally generated tsunami and expected it as high, same people might have researched or contacted local civil defense agencies and learned that the probability is lower than they expected. This theory too is supported by 4 respondents who stated that they are now, much better informed about the hazard than they have been prior to the Darfield quake. which leads for them to no evacuation.

4.4. NATURAL WARNING PERCEPTION

The Darfield earthquake was interpreted as a natural warning by 78.5%, with a mean estimated duration of about two and a half minutes, which is more than three times longer than the actual duration. This challenges the common natural warning indication of the experienced time, to be used as trigger for evacuation. It is indicated that people do have troubles with the estimation of time during extreme events, hence a warning interpretation might be difficult. An influencing factor on the natural warning perception might to the time of occurrence. The earthquake struck at 4.35am, which is before sunrise, at a time where no visual signs of the possible approaching hazard could have been interpreted. How this matter might influences the data cannot be determined, however it is evident that visual signs (e.g. sea level drop), serve as effective alert for an approaching tsunami(Gregg, 2006). Such visible signs before a tsunami usually complement and help to fill the missing link in mechanical tsunami warning systems, provided to alert vulnerable communities early through the use of sirens or other appliances (Gregg et al., 2006).

Further, it is uncertain if people in general link the ground-movement of an earthquake, with the hazard tsunami. One recent study undertaken in Thailand indicates that people who experience ground shaking from an earthquake mostly relate it to other sources than to the quake itself (Gregg et al., 2006). However, this link was not tested with this case study, as the natural warning perception is tested to fulfill the governmental prerequisites for evacuation, not the personal interpretation. The reason for misinterpretations of natural warnings, was not aimed to be exposed within this study, but it was aimed to identify what drives people to respond to it. The second model showed clearly that the warning experience itself is by far, not as important as other inter personal activities after the event. Also the case study showed that people both grossly over estimate and underestimate the earthquake duration. The time of ground shaking seems not to be easy for people to accurately estimate, which in questions its use as an indicator for self initiated tsunami evacuation.

4.5. TSUNAMI SIRENS KNOWLEDGE

Only 22.2% of the participants know about the basic principles of tsunami sirens. The interesting question was, ´Is this knowledge dependent on the existence of hazard sirens as warning from a distant source generated tsunami´? The answer was no, leading to the assumption that the relatively low knowledge about tsunami warning systems of 22.2% is not dependent on the use of tsunami sirens. This might have less importance where sirens are not used and therefore people do not rely on them, but might have catastrophic consequences in areas where people do. 73% of the people who are living in areas with tsunami sirens do not know how to distinguish between different tsunami generation sources in terms of sirens warning. The survey was conducted one month before and during the month of the siren implementation. The results suggest that people do not know that the sirens only work for a distant source, and only may work for regionally generated tsunamis. One possible explanation for this could be the implementation date. This might be misleading for some people, as the sirens are built after and activated within two years post Darfield earthquake. People might regard the sirens as an response to the resent earthquakes, and therefore interpret their functionality for locally generated tsunamis. During the survey condition, this theory was supported by 6 respondents who stated that: "*They (government) would not have built these sirens if they would not work for the earthquakes.*" This finding suggest that it might have been appropriate to accompany the implementation with strong public education programs about the use of the system

For a locally generated tsunami, methods to limit risk at an individual level seem to be limited. The knowledge about the hazard may be regarded as a preparation method, which would enable people to act appropriately to a natural warning. The coastline of Canterbury is a very low risk area for this hazard, which might limit level of readiness to respond, but even in high risk areas for locally generated tsunamis, research found that the levels of preparedness are relatively low(Paton et al., 2008). Initially, it was intended to measure the concept of hazard preparedness more accurately and include it in the analysis, but during the conduction of the survey, it became obvious that tsunami hazard preparedness is not measurable (with the in the questionnaire used questions). Most respondents indicated that individual preparation activities had improved as a result of the Darfield earthquake, in order to be prepared for another earthquake and not a tsunami. This lead to the problem that people prepared for another hazard, which made the intended tsunami-preparedness evaluation impossible.

5. CONCLUSION

This paper has presented a new approach to measure and conceptualize SVI on the disaster risk management cycle. The need to explore this new approach is motivated by two main drivers; firstly, current social vulnerability indicators fail to have a specific validity to a risk management activity. Secondly, the paper aims to contribute to the ongoing and much needed development of vulnerability assessment, which aims to achieve more disaster resilience, as the exploration of methods to understand who is at risk, will lead to better risk management by government and local decision makers (Dwyer et al., 2004). The presented conceptualization presents a method for more specific research towards the limitation of disaster risk. The presented case study highlights the problems arising out of general statements, which are not specified on disaster risk management action. It becomes obvious that social vulnerable demographic groups are not equally vulnerable in all phases of the disaster risk management. Whereby this paper could not identify those population groups most at risk, it presented the need for a more specific case study design when conducting SVI research. Further it becomes clear that hazard exposure can, in some instances, be influenced by social factors, and should therefore not be treated as a separate factor of the risk equation, besides hazard and vulnerability.

In general the case study design served well, to set an example for a more specific social vulnerability analysis. The identification of demographic SVI for the Warning phase was proven to be not exclusively determinable, which highlights the complexity of the concept of social vulnerability. This result also highlights that other general statements about vulnerable demographic groups have to be examined with care. The most significant finding is the individuals risk management activities being orientated on those of others. People who face uncertainties generated by potential hazards, orientate their behavior on the observed behavior of others. This finding is however one single case study. As it is one of the papers aims to set guidelines for future social vulnerability research, it is suggested to conduct numerous case studies, in geographically different locations, for all phases on the disaster risk management cycle, before drawing general conclusions from a single event. This case study presented a initial attempt to identify those most at risk for the warning phase, providing a pathway for future research.

6. Recommendations

This paper suggests that future SVI research, follows the presented conceptualization of SVI in order to create a number of indicators for all phases, deriving from different hazards and carried out in geographically different sites. This would allow a comprehensive social vulnerability index to be generated, including all disaster risk management activities.

The case study found some interesting results, which may be useful for emergency management agencies to implement in disaster risk management activities . As it is evident that more needs to be done to educate the public on the most appropriate behavior response to tsunami warnings (Bird, Chaqué-Goff, & Gero, 2011), some findings might be of specific importance to manage risk more efficiently.

The most outstanding finding is the above mentioned behavior orientation based on others, rather than on risk perception, hazard knowledge, natural warning perception, or response efficiency beliefs. This suggests that after an extreme event, peoples own behavior is dependent on that of others. This finding would support hazard education programs which are rather orientated on educating key figures within the population at risk, than those aimed at a broader scale, in order to achieve certain behavior.

Further this case study shows a lowering rate of natural warning response over time. Whereby the source of this decrease could not have been identified, this process highlights a development which might need to be counteracted, with some form of public education. These programs may also need to specify how people should interpret natural warnings in order to respond to them. This research highlighted that people mostly fail to estimate earthquake duration accurately and therefore might fail to perceive a natural warning. As the aim of this study is not to determine triggers for natural warning response, this paper does not present a solution to the problem, but rather states that time can mostly not be accurately assessed in an extreme event, hence should not serve as trigger for self initiated evacuation. Further, it can be stated that in times when disasters occur, emergency management agency's might need to focus also on further hazards in the public education programs, as these might be the next ones to occur. Finally, a comment has to be made regarding the time for the implementation of risk management tools, such as tsunami sirens. Such an implementation has to be accompanied with a major education campaign about its use, to avoid wrong assumptions, a higher rate of vulnerability, and therefore increased disaster risk after the implementation.

7. References

Ajzen, I. (1991). The theory of planned behavior. **Organizational Behavior and Human Decision Processes** 50, pp.179-211.

Amaratunga, C.A. and O'Sullican, T.L. (2006) In the path of disasters: psychosocial issues for preparedness, response, and recovery. **Prehospital and Disaster Medicine,** 21 (3), pp.149-55.

Anderson, M.B. (2000) **Vulnerability to disaster and sustainable development: a general framework for assessing vulnerability.** London, Routledge.

Ashburton District Council (2012a) **Local hazards** [Internet]. Available from <http://www.ashburtondc.govt.nz/services/civildefence/local+hazards.htm> [Accessed 22nd July 2012].

Bentler, P.M., and Chou, C.P. (1987) Practical issues in structural modeling. **Sociological Methods & Research**,16 (1), pp.78-117.

Berryman, K. (2005) **Review of tsunami hazard and risk in New Zealand**. Research Report 104, Lower Hutt, Institute of Geological and Nuclear Science New Zealand.

Bianchi, S.M. and Spain, D. (1996) Women, work, and family in America. **Population Bulletin** 51(3), pp.1-48.

Bird, D.K. (2009) The use of questionnaires for acquiring information on public perception of natural hazards and risk mitigation: a review of current knowledge and practice. **Natural Hazards and Earth System Sciences,** 9 (4), pp.1307-25.

Bird, D.K., Chaqué-Goff, C. and Gero, A. (2011) Human response to extreme events: a review of three post-tsunami disaster case studies. **Australian Geographer**, 42 (3), pp.225-39.

Birkman, J. (2005) **Danger need not spell disaster: but how vulnerable are we?** Research Brief 1, Institute for Environmental and Human Security, Bonn, United Nations University Press.

Birkman, J. (2006a) Measuring vulnerability to promote disaster-resilient societies: conceptual frameworks and definitions. In: Birkman, J. ed. **Measuring vulnerability to natural hazards: onwards disaster resilient societies**. Tokyo, United Nations University Press.

Birkman, J. (2006b) Indicators and criteria for measuring vulnerability: theoretical bases and requirements. In: Birkman, J. ed. **Measuring vulnerability to natural hazards: onwards disaster resilient societies**. Tokyo, United Nations University Press.

Birkmann, J. and Teichman, K.(2009.) In: Birkmann, J., Tetzlaff, G., Zental, K. eds. **Addressing the challenge: recommendations and quality criteria for linking disaster risk reduction and adaptation to climate change.** Bonn, DKKV Publication Series 38.

Blaikie, P., Cannon, T., Davis, I. and Wisner, B. (1994) **At risk: natural hazards, people's vulnerability, and disasters**. London, Routledge.

Britton, N.R. (1986) Developing an understanding of disaster. **Australian and New Zealand Journal of Sociology**, 22(2), pp.254-71.

Burton, I., Kates, R.W. and White, G.F. (1993) **The environment as hazard.** 2nd ed. New York, Guilford Press.

Cardona, O.D. (2004) The need for rethinking the concepts of vulnerability and risk from a holistic perspective: a necessary review and criticism for effective risk management. In Bankoff, G., Frerks, G., and Hilhorst, D. eds. **Mapping vulnerability: disasters, development and people**, London, Earthscan Publishers.

Cardona, O.D., Hurtado, J.E. and Chardon, A.C. (2003). **Indicators for disaster risk management**: **the notion of disaster risk**. Research Report ATN/JF-7907-RG, Universidad Nacional de Colombia, Instituto de Estudios Ambientales.

CERA (2012) **Land Status Map** [Internet], Canterbury Earthquake Recovery Authority. Available from: <http://cera.govt.nz/maps/land-status> [Accessed 9th August 2012].

Christchurch City Council (2012a) **Tsunami evacuation information for coastal Christchurch** [Internet]. Available from <http://resources.ccc.govt.nz/files/CCCTsunamiBrochure-informationondisastershazards.pdf> [Accessed 7th October 2011].

Clark, G.E., Moser, S.C., Ratick, S.J., Dow, K., Meyer, W.B., Emani, S., Jin, W., Kasperson, J.X., Kasperson, R.E., and Schwarz H.E. (1998) Assessing the vulnerability of coastal communities to extreme storms: the case of revere, MA, USA. **Mitigation and Adaptation Strategies for Global Change** 3, pp.59-82.

Crichton, D. (1999) The risk triangle. In Ingleton, J. ed. **Natural Disaster Management.** London, Tudor Rose, pp.102-3.

Cutter, S. L., Mitchell, J. T., and Scott. M. S. (2000) ‘Revealing the vulnerability of people and places: a case study of Georgetown county, South Carolina. **Annuals of the Association of American Geographers** 90(4), pp.713–37.

Cutter, S. L.. (1996) Vulnerability to environmental hazards. **Progress in Human Geography** 20(4), pp.529–39.

Cutter, S.L., Boruff, B.J. and Shirley, W.L. (2003) Social vulnerability to environmental hazards. **Social Science Quarterly**, 82 (2), pp.242-61.

Downing, T.E., Aerts, J., Soussan, J., Barthelemy, O., Bharwani, S., Ionesu, C., Hinkel, J., Klein, R.J.T., Mata, L.J., Martin, N., Moss, S., Purkey, D. and Ziervogel, G. (2006) **Integrating Social Vulnerability into Water Management.** Research Report 4, Oxford, Stockholm Environment Institute.

Dwyer, A., Zoppou, C., Day, S. and Roberts, S. (2004) **Quantifying social vulnerability: a methodology for identifying those at risk to natural hazards**. Research Report 14, Australian Government, Geoscience Australia.

ECAN (2007) **Tsunamis: The Q Files** [Internet], Environment Canterbury Regional Council. Available from <http://ecan.govt.nz/publications/General/q-files-tsunamis-booklet.pdf> [Accessed 14th August 2012].

ECAN (2012a) **Key information on 2010/11 Canterbury earthquakes** [Internet], Environment Canterbury Regional Council, Department for Environmental Quality and Hazards. Available from <http://ecan.govt.nz/advice/emergencies-and-hazard/pages/info-canterbury-earthquakes.aspx> [Accessed 15th July 2012].

ECAN (2012b) **Canterbury's tsunami hazard** [Internet], Environment Canterbury Regional Council, Department for Environmental Quality and Hazards. Available from <http://ecan.govt.nz/advice/emergencies-and-hazard/tsunami.aspx> [Accessed 13th July 2012].

ECAN (2012c) **Tsunami information for Christchurch, Pegasus Bay and Banks Peninsula after the 2010/2011 earthquakes** [Internet], Environment Canterbury Regional Council, Department for Environment Quality and Hazard. Available from <http://ecan.govt.nz/advice/emergencies-and-hazard/tsunami/pages/tsunami-info-chch.aspx> [Accessed 17th July 2012].

Enarson, E. and Morrow, B.H.(1997) A genders perspective: the voices of women. In Peacock W.G., Morrow B.H., and Gladwin, H. eds. **Hurricane Andrew: ethnicity, gender, and the sociology of disasters**, International Hurricane Center, Miami, Laboratory for Social and Behavioral Research, pp.116–40.

Enarson, E., and B. Morrow.(1998) **The Gendered Terrain of Disaster**. New York, Praeger.

Engle, N.L. (2011) Adaptive capacity and its assessment.**Global Environmental Change** 21(2), pp.647–56.

Fothergill, A. (1996) Gender, Risk, and Disaster. **International Journal of Mass** 14(1), pp.33–56.

Fothergill, A. (1998) The neglect of gender in disaster work: an overview of the literature. In Enarson, E., and Morrow, B.H. eds. **The gendered terrain of disaster: through women’s eyes**, Westport, Praeger.

Fothergill, A. and Peek, L.A. (2004) Poverty and disasters in the United States: a review of recent sociological findings. **Natural Hazards** 32, pp.89-110.

Frazer, L. and Lawley, M. (2000) **Questionnaire design administration: a practical guide**. Brisbane, John Wiley and Sons Australia Ltd.

Freshmap (2012) **Smart mapping system** [Internet] Available from <http://www.freshmap.co.nz/index.htm> [Accessed 13th May 2012].

Geonet (2012a**) Canterbury FAQ** [Internet], Earthquake Commission and Geological and Nuclear Sciences Institute New Zealand. Available from <http://info.geonet.org.nz/display/home/Canterbury+FAQ> [Accessed 20th August 2012].

Geonet (2012b) **New Zealand modified Mercalli Intensity Scale** [Internet], Earthquake Commission and Geological and Nuclear Sciences Institute New Zealand. Available from <http://www.geonet.org.nz/earthquake/geonet-modified-mercalli-intensity-scale.html> [Accessed 14th August 2012].

Geonet (2012c) **New Zealand Earthquake Report: September 4th 2010 at 4:35**. Earthquake Commission and Geological and Nuclear Sciences Institute New Zealand. Available from <http://www.geonet.org.nz/earthquake/quakes/3366146g-maps.html> [Accessed 14th March 2012].

Geonet (2012d) **Aftershocks** [Internet], Earthquake Commission and Geological and Nuclear Sciences Institute New Zealand. Available from <http://www.geonet.org.nz/canterbury-quakes/aftershocks/> [Accessed 14th July 2012].

Geonet (2012e) **Dec 23 2011: Christchurch hit again at Christmas** [Internet], Earthquake Commission and GNS Institute New Zealand. Available from <http://www.geonet.org.nz/news/archives/2011/dec-23-2011-christchurch-hit-again-at-christmas.html> [Accessed 14th July 2012].

GNS (2012a) **Tsunami in New Zealand**. [Internet], Geological and Nuclear Sciences Institute New Zealand. Available from <http://gns.cri.nz/Home/Our-Science/Natural-Hazards/Earth-s-Forces/Tsunami/Tsunami-in-New-Zealand> [Accessed 21th July 2012].

GNS (2012b) **2010 Darfield (Canterbury) Earthquake** [Internet], Geological and Nuclear Sciences Institute New Zealand. Available from <http://www.gns.cri.nz/Home/News-and-Events/Media-Releases/Most-damaging-quake-since-1931/Canterbury-quake/Darfield-Earthquake> [Accessed 14th August 2012].

GNS (2012c) **6.3 magnitude earthquake part of aftershock sequence: 25/02/2011** [Internet], Geological and Nuclear Sciences Institute New Zealand. Available from < http://www.gns.cri.nz/Home/News-and-Events/Media-Releases/earthquake-part-of-aftershock-sequence> [Accessed 19th September 2012].

Gorman, P. (2012) **Time to flee local tsunami: analyst**. The Press [Internet], 26 June. Available from: <http://www.stuff.co.nz/the-press/news/7168492/Time-to-flee-local-tsunami-analyst> Accessed 22 July 2012}.

Gregg, C. E., Houghton, B.F., Paton,D.,Lachman, R., Johnston, D.M. and Wongbusarakum, S. (2006) Natural warning signs of tsunamis: human sensory experience and response to the 2004 Great Sumatra Earthquake and tsunami in Thailand. **Eathquake Spectra,** 22 (3), pp.671-91.

Heinz Center for Science, Economics, and the Environment (2000) **The hidden costs of coastal hazards: implications for risk assessment and mitigation**. Covello, Island Press.

Hewitt, K. (1997) **Regions of risk: a geographical introduction to disasters**.United Kingdom, Longman.

Jackson, D.L. (2003) Revisiting sample size and number of parameter estimates: Some support for the N:q hypothesis. **Structural Equation Modeling** 10 (3), pp.128-141.

Kenny, D.A. (2012) **Structural Equation Modeling** [Internet]. Available from <http://davidakenny.net/cm/causalm.htm> [Accessed 12th July 2012].

Kline, R.B. (2011) **Principles and Practice of Structural Equation Modeling.** 3rd ed. New York, Guilford Press.

Levin, B. and Nosov, M. (2009) **Physics of tsunamis**. Dordrecht, Springer.

Lion, R., Meertens, R.L. and Bot, I. (2002) Priorities in information desire about unknown risks. **Risk Analysis,** 22 (4), pp.765-76.

Morgan, M.G., Fischhoff, B., Bostrom, A., Atman, C.J. (2001) **Risk communication: a mental models approach**. Cambridge, Cambridge University Press.

Morrow, B.H. (1999) Identifying and mapping community vulnerability, **Disasters** 23, pp. 1–18.

Ngo, E. B. (2001) When disasters and age collide: reviewing vulnerability of the elderly.**Natural Hazards Review** 2(2) pp. 80–9.

O'Brien, P., and Mileti. D. (1992) 'Citizen participation in emergency response following the Loma Prieta earthquake. **International Journal of Mass Emergencies and Disasters** 10, pp. 71–89.

Owens, I.F., Kirk, R.M., Bell, D.H., Cowan, H. Pettinga, N. and Todd, D. (1994) **Natural hazards in Canterbury**. Research Report 94 (19), Christchurch, Canterbury Regional Council.

Paton, D. (2008) Risk communication and natural hazard mitigation: how trust influences its effectiveness. **International Journal of Global Environmental Issues** 8 (1), pp.2-16.

Paton, D., Houghton, B.F., Gregg, C.E., McIvor, D., Johnston, D.M., Bürgelt, P., Larin, P., Gill, D.A., Ritchie, L.A., Meinhold, S., and Horan, J. (2008) Managing tsunami risk in coastal communities: identifying predictors of preparedness. **Australian Journal of Emergency Management** 23(1), pp.4-9.

PCEE Ninth Pacific Conference on Earthquake Engineering, . Auckland, (2011). **Building an earthquake-resilient society**, Holden, C., Beavan, J., Fry, B., Reyners, M., Ristau, J., VanDissen, R, Villamor, P., and Quigley, M., Auckland.

Peacock, W.,. Morrow, B. H, and Gladwin, H. (2000). **Hurricane Andrew and the reshaping of Miami: ethnicity, gender, and the socio- political ecology of disasters**. International University, Florida, International Hurricane Center.

Puente, S. (1999) Social vulnerability to disaster in Mexico City. In Mitchell, J. K. ed. **Crucibles of hazard: mega cities and disasters in transition.** Tokyo, United Nations University Press, pp. 295–334.

Rygel L., O'Sullivan, D. and Yarnal, B. (2006) A method for construction a social vulnerability index: an application to hurricane strom surges in a developed country. **Mitigation and Adaptation Strategies for Global Change,** 11 (3), pp.741-64.

Schipper, L., and Pelling, M. (2006) Disaster risk, climate change and international development: scope for, and challenges to, integration. **Disasters** 30 (1), pp.19-38.

Schreiber, J.B., Stage, F.K., King, J., Nora, A. and Barlow, E.A. (2006) Reporting structural equation modeling and confirmatory factor analysis results: a review. **The Journal of Educational Research** 99(6), pp.323-39.

Schreiber, J.B., Stage, F.K., King, J., Nora, A. and Barlow, E.A. (2006) Reporting structural equation modeling and confirmatory factor analysis results: a review. **The Journal of Educational Research**, 99 (6) July, pp.323-37.

Searle, W. (1994) **Disasters and social science: a New Zealand bibliography**. Wellington, Ministry of Civil Defence.

Slovic P, Fischhoff B. and Lichtenstein S. (1978) How safe is safe enough: a psychometric study of attitudes towards technological risks and benefits. **Policy Sciences** 9, pp.127–152.

Slovic P. (2000) **The perception of risk**. London: Earthscan Publications Ltd.

Statistics NZ (2012a) **Dwelling and household estimates** [Internet], New Zealand's national statistical office. Available from <http://www.stats.govt.nz/browse_for_stats/population/estimates_and_projections/dwelling-and-household-estimates.aspx#households> [Accessed 7th August 2012].

Statistics NZ (2012b) **QuickStats about Canterbury region** [Internet], New Zealand's national statistical office. Available from <http://www.stats.govt.nz/Census/2006CensusHomePage/QuickStats/AboutAPlace/> [Accessed 9th August 2012].

Tanaka, J.S. (1987) How big is big enough: sample size and goodness of fit in structural equation models with latent variables. **Child Development** 58, pp.134-46.

UNDP (2004) **Reducing disaster risk: a challenge for development**. New York, United Nations Development Programme.

UNISDR (2009) **Terminology on disaster risk reduction**. Geneva, United Nations International Strategy for Disaster Reduction.

Wachinger, G., and Renn, O. (2010) **Risk perception and natural hazards**. Research Report WP3, Stuttgart, CapHaz-Net Consortiom.

Waimakariri District Council (2012) **Waimakariri District risks and hazards** [Internet]. Available from <http://www.waimakariri.govt.nz/civil_defence_home/waimakariri-civil-defence-risks-and-hazards.aspx> [Accessed 21st July 2012].

APPENDICES

APPENDIX 1: Tsunami innundation zones for Christchurch City

WHAT IS A TSUNAMI?

A tsunami is a series of waves most commonly caused by an earthquake beneath the sea floor. As tsunamis enter shallow water near land, they increase in height and can cause loss of life, injury and property damage where they come ashore. They can occur at any time of the day or night, under any and all weather conditions, and in all seasons. Beaches open to the ocean, bay entrances, estuaries, tidal flats, and coastal rivers are especially vulnerable to tsunamis.

WHAT ARE THE DIFFERENT TYPES OF TSUNAMI?

Tsunamis are categorised into three groups:

Distant source tsunamis, which take more than three hours to reach New Zealand. A distant source tsunami that will affect the City and Banks Peninsula is likely to be generated around South America or Alaska. When a tsunami has been generated from these areas, it will not reach the City and Peninsula coastline for an estimated 12 to 14 hours. There will be sufficient time to issue a warning and activate the Coastal Evacuation Plan which has been developed by the Police and Christchurch City Council.

Regional source tsunamis, which take one to three hours to reach New Zealand. The sources of this type of tsunami include earthquakes and volcanoes in tectonically active areas to the north and east of New Zealand. Regional source tsunamis are generally considered less likely than distant and local source tsunamis and are a very low risk to the City and Banks Peninsula.

Local source tsunamis, which take less than an hour to reach the nearest New Zealand coastline. When a local source tsunami is generated by a strong offshore earthquake, the first waves would reach the coast within minutes after the ground stops shaking. Feeling an earthquake could be your only warning. The probability of a local source tsunami impacting on the City and Banks Peninsula coastline is considered low.

PLEASE KEEP THIS LEAFLET FOR REFERENCE

WHERE CAN I GO FOR MORE INFORMATION?

Check out the following websites:
www.ccc.govt.nz/CDEM
www.getthru.govt.nz/
www.cdemcanterbury.govt.nz/

or contact Environment Canterbury
for a copy of The Q Files -Tsunamis booklet

CHRISTCHURCH

GET READY GET THRU

CANTERBURY Civil Defence Emergency Management Group

CHRISTCHURCH

WHAT CAN I DO TO PROTECT MYSELF FROM A TSUNAMI?

- Develop a household evacuation plan. Everyone in your household needs to know what to do on their own to protect themselves in case of emergency
- Know where to go to be out of the tsunami evacuation area (coloured pink on the map) and move beyond the Police cordoned off area. Arrange to stay with family or friends who live well away from the evacuation area or prepare to go to a designated Welfare Centre - listen to the radio for details about the location of the Welfare Centre(s).

HOW DO I KNOW WHEN TO EVACUATE?

Listen to the radio stations listed below for information. For a distant source tsunami the Police and Civil Defence will bring together their teams and start evacuating the area coloured pink on the map.
A local source tsunami is unlikely to be generated near Christchurch or Banks Peninsula. However, if you feel an earthquake lasting more than several seconds, during which you have difficulty standing or walking, immediately move out of the evacuation area. Strong ground shaking in Christchurch will most likely come from an earthquake on an inland fault that won't generate a tsunami, but there is a possibility that it is from an earthquake on a fault in Pegasus Bay, and a small possibility that this has generated a tsunami. If you notice a sudden drop or rise in sea level, immediately move inland or to high ground.

WHAT SHOULD I HAVE IN MY GETAWAY KIT?

You should prepare a getaway kit containing only essential items you can carry. The kit should be adapted to your family's needs, but only include those important items mentioned below that you can easily carry. Have it ready to go for immediate evacuation.
Your kit should include:
- Cash and credit cards
- Family documents
  - Birth and marriage certificates
  - Driver's licences and passports
  - Financial information (insurance policies, mortgage information etc)
  - Family photographs
- Personal items
  - Medical items
  - Towels, soap, toothpaste, toilet paper and sanitary items
  - Hearing aids, glasses, mobility aids for elderly or vulnerable members of your household
  - Warm clothing

PETS

Strict rules apply if you wish to take pets on public transport or to a Welfare Centre where they will be registered and cared for by Christchurch City Council animal control and RSPCA staff:
- dogs – muzzled, on a lead and under strict control
- cats – in suitable cage or box
- birds – in suitable cage

WHAT SHOULD I DO BEFORE I EVACUATE

- Check whether your neighbours require assistance
- Leave a telephone book outside your door to indicate to emergency staff that you have evacuated
- Secure your home.

WHERE DO I EVACUATE TO?

- The map shows the coastal evacuation area – coloured pink. You must move well beyond this area
- If you live near the coast or Estuary between Cannon Hill through to Taylor's Mistake you might choose to stay with friends or family who live higher up in these hillside suburbs
- If you don't have time to travel to high ground, but are in a multi-story building, go to an upper level.
- If you are on the beach and unable to get to high ground, go inland as far as you can
- Where possible use the route through the coastal evacuation area closest to your home indicated by the evacuation route on the map. This will help to get people out of the area more efficiently and reduce possible congestion.

DO NOT RETURN TO YOUR HOME UNTIL CIVIL DEFENCE ANNOUNCE THE EMERGENCY IS OVER AND IT IS SAFE TO GO BACK.

The first tsunami wave is often not the largest; successive waves may be spaced many minutes apart and continue to arrive for many hours.

WHERE CAN I STAY UNTIL THIS IS OVER?

- Stay with family or friends who live well outside the evacuation area or go to a designated Welfare Centre - listen to the radio for details about the location of the Welfare Centre(s).

WHAT IF I CANNOT RETURN HOME?

Longer-term accommodation will be organised if it is not possible for you to return home because of the impact of the tsunami.

WHICH RADIO STATIONS SHOULD I LISTEN TO?

Newstalk ZB 1098AM
More FM 92.1FM
The Breeze 94.5FM

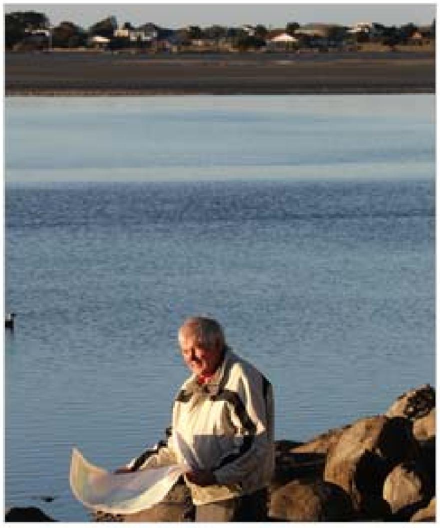
APPENDIX 2: Tsunami Sirens Article from the 26th June 2012

THE PRESS
press.co.nz

Time to flee local tsunami - analyst

PAUL GORMAN

Last updated 05:00 26/06/2012



STACY SQUIRES/Fairfax NZ

DANGER ZONE: Retired Christchurch engineer Ian Duff has calculated any Pegasus Bay tsunami could take an hour to reach shore. He is questioning the city council's decision to use the new warning sirens only for more distant events.

Any tsunami generated in a major Pegasus Bay earthquake could take nearly an hour to reach shore, a Christchurch man says.

Retired marine electronics engineer Ian Duff said the results of his calculations had come as a surprise.

He wanted to know why the Christchurch City Council's $550,000 tsunami warning system could not be "competently redesigned" for use for locally generated events, given that amount of notice of tsunami arrival.

"The absence of proper consideration being given to locally generated tsunamis is presumably based on the erroneous assumption that there just isn't time to warn of a local event," he said.

"To my surprise, the transit time from the Pegasus Canyon to, say, the beach in front of Pegasus Town works out at a little under one hour, which I think is plenty of time to get people away from the coast, given a reliable early warning.

"My gut feeling was it would take about quarter of an hour."

The canyon was a "reasonably valid" choice for a large quake source, he said. "It's a very obvious feature on Google Earth and on nautical charts and it has the look of having had a violent origin.

"It could easily have subduction characteristics as well as strike-slip [horizontal motion] when it moves, and because it is steep-sided there is a risk of a big underwater landslide when it does move."

Only a "small fraction" of offshore quakes caused tsunami, depending on the nature of the ground movement, Duff said.

"In general, it is very rare for a quake below magnitude 7 to create a tsunami."

He wanted to be a "realist, not an alarmist".

Duff's method was to measure 13 equidistant points in a straight line from the 1000 metre-deep contour in the canyon to the beach near the Ashley River mouth.

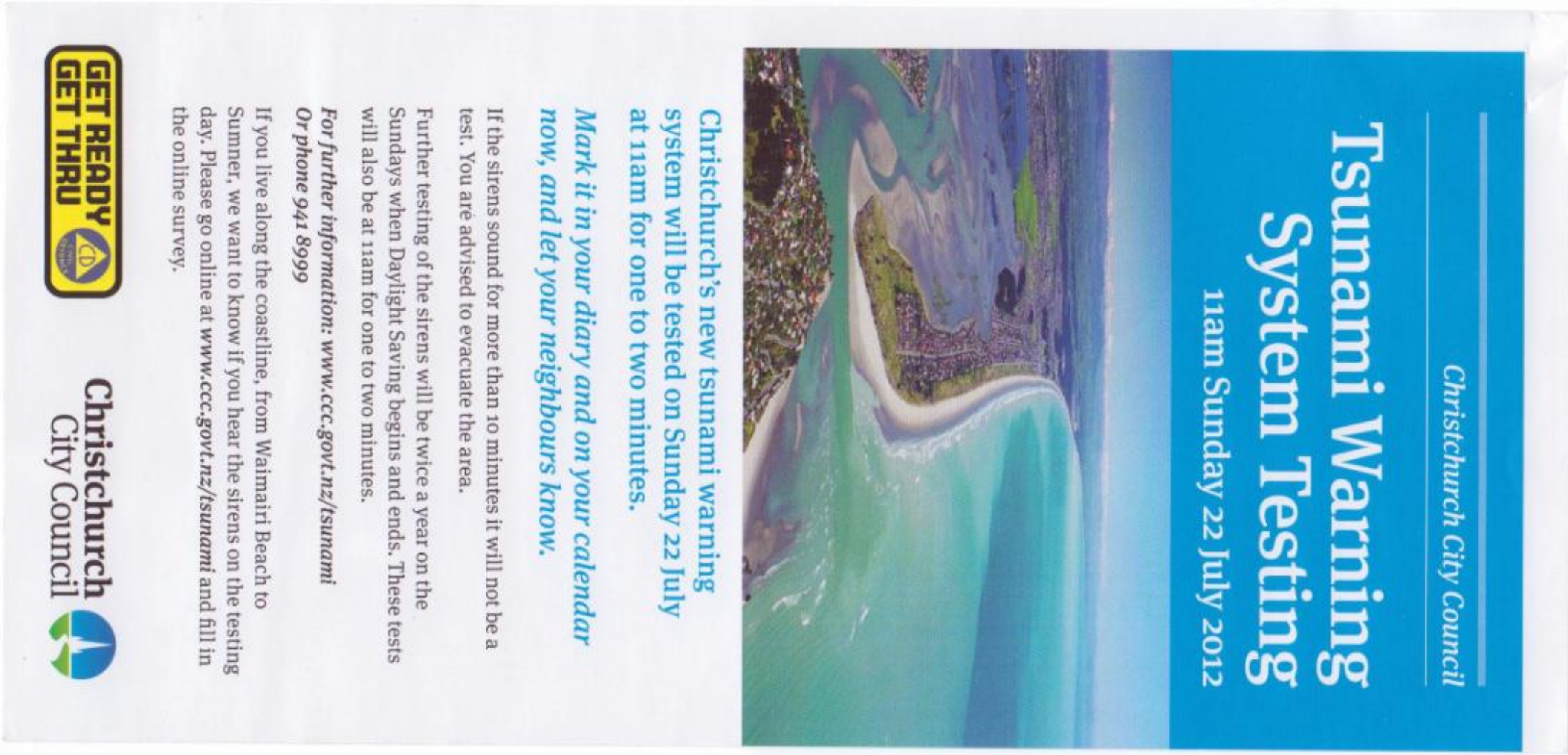
Each point was about 5.8 kilometres from the next and for each he calculated the "waveguide speed", the square root of the acceleration of gravity – 9.8 metres per second per second – multiplied by the water depth there.

From that, Duff worked out the time it would take a tsunami to travel from one point to the next.

The total travel time along the line was 3403 seconds, or 56 minutes and 43 seconds, with an estimated error of plus or minus 10 per cent.

"The nitty-gritty is that our tsunami warning siren system should be competently redesigned to give adequate warning of locally generated tsunami in addition to trans-Pacific ones," he said.

APPENDIX 3: Tsunami Sirens Information Folder



Christchurch City Council

Tsunami Warning System Testing

11am Sunday 22 July 2012

Christchurch's new tsunami warning system will be tested on Sunday 22 July at 11am for one to two minutes.

Mark it in your diary and on your calendar now, and let your neighbours know.

If the sirens sound for more than 10 minutes it will not be a test. You are advised to evacuate the area.

Further testing of the sirens will be twice a year on the Sundays when Daylight Saving begins and ends. These tests will also be at 11am for one to two minutes.

For further information: www.ccc.govt.nz/tsunami
Or phone 941 8999

If you live along the coastline, from Waimairi Beach to Sumner, we want to know if you hear the sirens on the testing day. Please go online at ***www.ccc.govt.nz/tsunami*** and fill in the online survey.

GET READY GET THRU

Christchurch City Council

APPENDIX 4: Study Site Survey Approaching Statistics

									Weekday('1')													
									Morning*							Midday**						
										Number							Number					
											ineligible Respondent							ineligible Respondent				
District	**Area**	**Area code**	House No.	**Hrs Total (4,5/100houses)**	**No Total Participated**	**No Total Moved**	**No Total Approached**	**Weekday Hrs**	**Hrs**	unwilling Respondent[1]	Presence[2]	Age[3]	Distressed[4]	Moved[5]	Partizipated	**Hrs**	unwilling Respondent[1]	Presence[2]	Age[3]	Distressed[4]	Moved[5]	Partizipated
Waimakariri	Waikuku Beach	WIB	169	9	16	3	52	3	1,5	1	2	0	0	0	0	1,5	1	2	0	1	2	3
Waimakariri	Woodenend Beach	WOB	71	4,5	5	3	21	1,5	1,5	0	1	0	0	0	0							
Waimakariri	Pines Beach	PIB	82	4,5	5	3	19	1,5								1,5	0	3	0	0	0	0
Christchurch City	Brooklands	BRO	178	9	12	3	42	3								1,5	2	2	0	0	0	2
Christchurch City	North New Brighton	NNB	249	13,5	12	9	99	4,5	1,5	8	4	0	0	4	3	1,5	6	3	0	1	1	2
Christchurch City	New Brighton	NBN	311	18	9	6	106	6	3	12	2	0	0	2	0	1,5	9	3	0	0	1	2
Christchurch City	Southshore/South New Brigton	SOH	359	18	24	7	109	6	1,5	8	3	0	0	0	2	1,5	4	1	0	1	1	3
Christchurch City	Ferrymead	FEM	236	13,5	8	1	39	4,5	1,5	1	0	0	0	0	3	1,5	2	1	0	0	0	3
Christchurch City	Moncks Bay	MOB	246	13,5	6	1	37	4,5	1,5	0	1	0	0	0	2	1,5	0	0	0	0	0	1
Christchurch City	Sumner	SUM	285	13,5	16	3	79	4,5	1,5	4	1	0	0	0	0	1,5	1	2	0	1	0	3
Ashburton	Rakaia River Mouth	RRM	63	4,5	4	0	9	1,5	1,5	0	2	0	0	0	2							
Ashburton	Hakatere	HAK	52	4,5	7	1	14	1,5														
Ashburton	Rangitata River Mouth	RAR	65	4,5	3	0	4	1,5								1,5	0	0	0	0	0	2
				130,5	**127**	**40**	**609**	43,5	15	34	16	0	0	6	12	15	25	17	0	4	5	21

								Saturday ('2')																				
Afternoon***								Morning*							Midday**							Afternoon***						
Hrs	Number of Persons Approached						Saturday Hrs	Hrs	Number of Persons Approached						Hrs	Number of Persons Approached						Hrs	Number of Persons Approached					
	unwilling Respondent[1]	ineligible Respondent: Presence[2]	Age[3]	Distressed[4]	Moved[5]	Partizipated			unwilling Respondent[1]	ineligible Respondent: Presence[2]	Age[3]	Distressed[4]	Moved[5]	Partizipated		unwilling Respondent[1]	ineligible Respondent: Presence[2]	Age[3]	Distressed[4]	Moved[5]	Partizipated		unwilling Respondent[1]	ineligible Respondent: Presence[2]	Age[3]	Distressed[4]	Moved[5]	Partizipated
							3	1,5	6	4	0	1	1	2								1,5	0	4	0	0	0	4
							1,5	1,5	4	1	0	0	2	2														
							1,5															1,5	1	6	0	0	3	2
1,5	1	0	1	0	2	1	3	1,5	7	1	1	0	1	3	1,5	0	1	0	0	0	1							
1,5	4	6	0	0	0	1	4,5	1,5	4	0	0	0	0	1	1,5	2	2	0	1	1	0	1,5	7	11	0	0	2	1
1,5	2	1	0	0	0	1	6	3	5	2	0	0	0	0	1,5	6	5	0	1	1	1	1,5	5	4	0	1	2	0
3	6	2	0	0	0	5	6	1,5	4	2	0	0	0	3	1,5	3	8	0	0	2	1	3	4	7	0	0	0	4
1,5	3	0	0	0	0	1	4,5	1,5	3	2	0	0	0	0	1,5	4	0	0	0	0	0	1,5	2	1	0	0	0	0
1,5	1	2	0	0	0	1	4,5	1,5	2	0	0	0	0	0	1,5	4	2	0	0	1	0	1,5	1	0	0	0	0	1
1,5	2	8	0	0	2	1	4,5	1,5	4	2	0	0	0	3	1,5	5	11	0	0	0	1	1,5	2	5	0	0	0	3
							1,5	1,5	0	1	0	0	0	0														
1,5	1	2	0	0	0	4	1,5								1,5	0	1	0	0	0	1							
							1,5	1,5	0	0	0	0	0	0														
13,5	20	21	1	0	4	15	43,5	18	39	15	1	1	4	14	12	24	30	0	2	5	5	13,5	22	38	0	1	7	15

	Sunday('3')																				
	Morning*							Midday**							Afternoon***						
Sunday Hrs	**Hrs**	Number of Persons Approached						**Hrs**	Number of Persons Approached						**Hrs**	Number of Persons Approached					
		unwilling Respondent[1]	ineligible Respondent				Partizipated		unwilling Respondent[1]	ineligible Respondent				Partizipated		unwilling Respondent[1]	ineligible Respondent				Partizipated
			Presence[2]	Age[3]	Distressed[4]	Moved[5]				Presence[2]	Age[3]	Distressed[4]	Moved[5]				Presence[2]	Age[3]	Distressed[4]	Moved[5]	
3	1,5	1	4	0	0	0	3	1,5	3	3	0	0	0	4							
1,5								1,5	3	4	0	0	1	3							
1,5															1,5	1	0	0	0	0	3
3	1,5	8	1	1	0	0	3								1,5	1	0	0	0	0	2
4,5	1,5	4	0	0	0	0	1	1,5	6	0	0	0	1	1	1,5	5	4	0	0	0	2
6	1,5	7	1	0	0	0	2	3	7	14	0	0	0	1	1,5	4	0	0	0	0	2
6	1,5	4	0	0	0	0	1	1,5	1	5	0	0	1	3	3	4	11	0	0	3	2
4,5	1,5	1	0	0	0	0	0	1,5	4	0	0	0	1	0	1,5	5	1	0	0	0	1
4,5	1,5	3	0	0	0	0	0	1,5	1	0	0	0	0	0	1,5	7	6	0	0	0	1
4,5	1,5	3	2	0	0	0	1	1,5	0	3	0	0	1	2	1,5	3	1	0	0	0	2
1,5								1,5	0	2	0	0	0	2							
1,5								1,5	0	2	0	0	1	2							
1,5															1,5	0	1	0	0	0	1
43,5	12	31	8	1	0	0	11	17	25	33	0	0	6	18	15	30	24	0	0	3	16

[1]Approached persons were not willing to participate at the study for certain reasons.

[2] Approached persons were not present in the tsunami innundation zone to this area when the 4th Sept. earthquake struck.

[3]Approached persons are under the age of 18 years old.

[4] Respondent showed signs of disstress and were therefore excluded from participating.

[5]Approached persons relocated between 4th September 2010 and XXXCCth August 2012

*Morning is defined as the timespan from 8am unitl 11am ('1')

**Midday is defined as the timespan from 11am until 2pm ('2')

***Afternoon is defined as the timespan from 2pm until 5pm ('3')

QUESTIONNAIRE

EARTHQUAKE RESPONSE

University of Natural Resources and Applied Life Sciences, Vienna

Lincoln University Te Whare Wānaka o Aoraki

Participant Identification No: _______ Questionnaire No: _______

1. Please indicate, on the map, where you were when the earthquake on the 4 Sept. 2010 at 4:36 struck.

___ *Fill in area code.* □1 Yes *Tick 'Yes', if respondent was in his/her private home (ground storey).*

2. Would you say that it was difficult to stand up during the quake?

□1 Yes □2 No

3. How long did the earthquake feel like it lasted?

___ Minutes ___ Seconds □1 Did not feel earthquake at all.

4. Did you have access to a motorised vehicle (car or motorbike) after the earthquake struck?

□1 Yes □2 No

5. Did you receive any information that you understood as a tsunami warning when the earthquake struck?

□1 Yes □2 No

If respondent choose 'Yes', raise the following questions, if not go to question 6.

5.1. What was this information?

____

5.2. From what source did you receive this information?

____

5.3. How long after the earthquake did you receive this information?

___ Minutes ___ Seconds

6. How did you react when the earthquake struck?

□1 Stayed where I was. □2 Went to another place to evacuate from possible tsunami.

□3 Something else. Please specify:____

If respondent choose 'Went to another place evacuate from possible tsunami', raise the following questions, if not, go to Question 7.

6.1. Were you accompanied by other people, when you moved to a new location?

□1 Yes (please specify) □2 No

If respondent said 'Yes', raise the following questions, if not go to Question 6.2.

6.1.1. Were any of this people in a dependent relationship with you?

Tick persons mentioned.

□1A Children □1B Elderly □1C Other(s)

6.2. How long did it take you to make the decision to evacuate?

___ Hours ___ Minutes___ Seconds

6.3. How long did it take you to reach a place out of the 'tsunami danger' zone (from post-earthquake location to destination)?

Hours Minutes Seconds

6.4. How did you get to the other place?

☐1 Motorised vehicle ☐2 Cycle ☐3 Other form of movement.

6.5. How long did you stay out of the 'tsunami-danger-zone' for?

___ Hours ___ Minutes___ Seconds

6.6. Did you receive any information which you understood as an 'all-clear' message that assured you that no tsunami was caused by the earthquake?

☐1 Yes ☐2 No

If respondent choose 'Yes', raise the following questions, if not go to question 7.

6.6.1. What was this information?

____

6.6.2. From what source did you receive this information?

____

7. In the first 15 minutes after the earthquake, how did the *majority* of the people that you saw react?

☐1 Stayed where they were. ☐2 Appeared to be evacuating.

☐3 Something else. Please specify: ___________________________________

8. Did you communicate with people regarding a decision to evacuate after the earthquake struck?

☐1 Yes ☐2 No

If respondent answered 'Yes', raise the following questions, if not go to question 9.

8.1. With whom did you communicate?

☐1 Family member(s) ☐2 Other(s)

8.2. Did the content of this communication influence your decision?

☐1 Yes ☐2 No

9. Were you within two blocks of the coast, an estuary or a river mouth when one of the major aftershocks on 22nd February, 3rd June or 23rd December struck?

☐1 Yes (please specify) ☐2 No

☐1A 22 Feb.2011 (12:51 p.m.) ☐1B 3 June 2011 (1:00 p.m.) ☐1C 23 Dec. 2011 (1:58 p.m.)

If the respondent lists more than one aftershock event, raise the following question, if not go to question 9.2.
If the respondent answers 'No', then go to Question10.

9.1. Which one did you experience as the strongest?

☐1A 22 Feb.2011 (12:51 p.m.) ☐1B 3 June 2011 (1:00 p.m.) ☐1C 23 Dec. 2011 (3.18 p.m.)

I now need to ask you the same four questions about [*name date of event*] earthquake.

9.2. Regarding the [name date of event] earthquake, would you say that it was difficult to stand up during it?

☐1 Yes ☐2 No

9.3. How long did that earthquake feel like it lasted?

___ Minutes ___ Seconds

9.4. How did you react when that earthquake struck?

☐1 Stayed where I was. ☐2 Went to another place to evacuate from possible tsunami.

☐3 Something else. Pleasespecify:___________________________________

9.5. In the first 15 minutes after the earthquake, how did the majority of the people that you saw react?

□1 Stayed where they were. □2 Appeared to be evacuating.

□3 Something else. Please specify: ____

10. Suppose that you were located within two blocks of the coast, an estuary or a river mouth. Would you now behave differently than you did at the 4th September earthquake, if you felt an earthquake of similar strength?

□1 Yes □2 No

If respondent answered 'Yes', raise the following questions. If not, go to Question 11.

10.1. What would you do?

□1 Stay where I am. □2 Go to another place to evacuate from possible tsunami.

11. Do you know if tsunami sirens are installed, or are to be installed in the area where you currently reside?

□1 Yes, they are. □2 Yes, they will be. □3 No, they won't be. □4 I'm not sure.

12. Tsunami sirens are used in some Canterbury regions for the purpose of tsunami warning. Do you think that sirens would save lives, if a tsunami would be caused by a very strong, locally generated earthquake?

□1 Yes □2 No

If respondent answered 'No', raise the following questions. If not, go to Question 12.

12.1. Why do you think that tsunami sirens would not save lives, if a tsunami was caused by a very strong, locally generated earthquake?

□1 Tsunami sirens do not work for locally generated earthquakes. □2 Something else.

13. How often is a damaging tsunami likely to occur where you now live? Once in ...

□1 less than 10 years □5 less than 5,000 years

□2 less than 100 years □6 less than 10,000 years

□3 less than 500 years □7 less than 50,000 years

□4 less than 1,000 years □8 more than 50,000 years

14. Is it likely that a tsunami will affect you in the future?

□1 Yes □2 No

15. If a tsunami were to be generated by a local earthquake, how much could you increase your chance of survival by responding to it? Please put an X on the bar that indicates the level of increase.

Hand questionnaire and pen to respondent.

Not at all Very much

|--|

16. How safe do you feel when considering the risk of a tsunami?

Not at all Very safe

|--|

17. How prepared do you think you are for a possible tsunami?

Not at all Very prepared

|--|

18. How quick do you think a tsunami could reach the coast after an earthquake occurs?

___ Hours ___ Minutes ___ Seconds

19. Do you have a 'Get-away-Kit' in the case of an event like a tsunami?

☐$_1$ Yes ☐$_2$ No

If respondent answered 'Yes', raise the following questions, if not go to question 20.

19.1. Can you please list five main items in this package:

☐$_A$ ☐$_B$ ☐$_C$ ☐$_D$ ☐$_E$ *Tick boxes if appropriate items are named.*

20. Do you have a 'Household Emergency Plan'?

☐$_1$ Yes ☐$_2$ No

If respondent answered 'Yes', raise the following questions. If not, go to Question 21.

20.1 If you can't contact your household members after an earthquake or tsunami, where have you planned to meet them?

________________ *Fill in Place mentioned by the respondent.* ☐$_A$ *Tick box if no place is mentioned.*

If respondent lives in a single household, go to the next question.

21. What is your native nationality?

____

If respondent nationality is not New Zealander, ask the following questions. If Kiwi, go to Question 22.

21.1. Have you heard about a tsunami in your native country?

☐$_1$ Yes ☐$_2$ No

21.2. Have you experienced a tsunami in your native country?

☐$_1$ Yes ☐$_2$ No

21.3. Have you received tsunami education or awareness-raising messages in your native country?

☐$_1$ Tsunami education ☐$_2$ Awareness-raising messages ☐$_3$ None

22. Have you experienced a tsunami in New Zealand?

☐$_1$ Yes ☐$_2$ No

23. Have you heard about a tsunami in New Zealand?

☐$_1$ Yes ☐$_2$ No

24. Have you experienced tsunami education or awareness raising activities in New Zealand?

☐$_1$ Tsunami education ☐$_2$ Awareness-raising messages ☐$_3$ None

25. At what level do you regard your knowledge about tsunamis?

Hand questionnaire and pen to respondent.

I know almost nothing about tsunamis — I am an expert

|--|

26. To what extent do you believe the government is able to cope with any possible disaster in New Zealand, in terms of providing basic needs (e.g., food, medicine, and shelter)?

Not at all — Completely able

|--|

27. How reliable do you think is the information provided by the local and national government agencies regarding the probability of tsunamis?

Not reliable — Completely reliable

|--|

The final set of questions concern information about yourself. As with all the information in this questionnaire, this information will be treated with complete confidence, and will only be used to identify general trends and to describe our sample. This information is specifically needed to determine how representative the sample is of the general population.

So please tell me a little bit about yourself.

28. Sex. *(Do not ask)*

☐1 Male ☐2 Female

29. How religious/spiritual would you see yourself?

Not at all religious/spiritual — Very religious/spiritual

|--|

Hand demographic card to respondent.

30. What age group do you fall into? *(Show Card)*

____ *Fill in age group.*

31. What is your household's gross annual income (group)? *(Show Card)*

____ *Fill in income group.*

32. What is your current employment status (group)? *(Show Card)*

____ *Fill in employment group.*

33. What is your highest level of education (group)? *(Show Card)*

____ *Fill in education group.*

34. What is your marital status?

☐1 Single ☐2 Living with partner ☐3 Married

35. Are there other people living in your household?

☐1 Yes (please specify): ☐2 No (single-household)

☐1A Partner ☐1B Children ☐1C Parent(s)

☐1D Sibling(s) ☐1E Friend(s) ☐1F Other(s)

36. Are you currently holding a drivers licence for a car or motorbike?

☐1 Yes ☐2 No

If respondent answered 'Yes', raise the following questions. If not, the questionnaire is over. Go to Thank You.

36.1. Do you own a registered car or motorbike?

☐1 Yes ☐2 No

Now it's your turn! Do you have any questions about this study, now that you have participated in it?

[Answer any questions fully]

If you have any questions in the future, please feel free to contact either me or my supervisor. Thank you very much for your co-operation.

APPENDIX 6: Analyze sheet for earthquake response questionnaire

Question No.	Importance/Relevance for Research
1.	To ensure that respondent is qualified for evaluation of tsunami risk behaviour. -respondent had to be in the official Tsunami-Evacuation-Zone on Sept. 4th 2010-
2.	Parameter – 4-09 Earthquake Perception Categorisation into ≥MMI6 Yes (1) = Criteria for evacuation fullfilled No (2) = Criteria for evacuation Not fullfilled
3.	Parameter – 4-09 Earthquake Perception Categorisation depending on criteria at district level Yes (1) = Criteria for evacuation fullfilled No (2) = Criteria for evacuation Not fullfilled
4.	4-09 Event Mobility Yes(1) = Motorised event mobility given No(2) = Motorised event mobility Not given
5.	4-09 Tsunami Warning Yes(1) = Tsunami warning of any kind recieved No (2) = No tsunami warning recieved
5.1.	Content of Informaion (earthquake, tsunami)
5.2.	Source of Information
5.3.	Timing of Information recieved after earthquake
6.	4-09 Event Response (1) = Not responded in terms of tsunami evacuation (2) = Evatuated from possible tsunami (3) = Something Else
6.1.	Event Evacuation Behaviour (1) = Respondent was accompanied with other people, when he/she moved to a new location (2) = Respondent was alone when he/she moved to a new location
6.1.	Event Dependence Estimation Are dependent persons more vulnerable during disaster? (1) = Dependent Persons were with the respondent when he/she moved to a new location. (2) = Dependent Persons were NOT with the respondent when he/she moved to a new location.
6.2.	Evacuation Time Decision Time for Evacuation
6.3.	Parameter - Event Exposure Is the respondent out of 'danger-zone' in time? Def.: Due to CC a tsunami could arise after (*differing data in districts)* minutes.
6.4.	Parameter - Evnet Mobility (1) = Respondent used motorised vehicle to move to a new location (2) = Respondent used a cycle to move to a new location (3) = Respondent used other form of movement to get to a new location
6.5.	Paramter - Event Evacuation Time Did the respondent stayed out of the tsunami endangered zone for long enough?
6.6.	Event Information (1) = Respondent received information which he/she understood as an ‘all clear’ message that assured him/her that no tsunami was caused by the earthquake (2) = Respondent did NOT receive information which he/she understood as an ‘all clear’ message that assured him/her that no tsunami was caused by the earthquake

6.6.	Event Information Content of 'all clear' informaiton
6.6.	Event Information Source of 'all clear'information
7.	Parameter – Behaviour Accordance (1) = Majority of people stayed in 'Tsunami Endangered Zone' (2) = Majority of people appeared to be evacuation from 'Tsunami Endangered Zone' (3) = Something else
8.	Parameter - Event Communication (1) = Event Communication Given (2) = Event Communication Not Given
8.1.	Parameter - Event Communication (1) = Event Communication with Family Member(s) (2) =Event Communication with Non Family Member(s) (3) = Event Communication with Family Member(s) and Other(s)
8.2.	Parameter- Event Communication (1) = Persumed Event Communication Influence (2) = No Persumed Event Communication Influence
9.	Aftershocks Event Location (2) = Respondent is Not located in 'Tsunami Danger Zone' when aftershock struck (1A)=(3)= Respondent located in 'Tsunami Danger Zone' at 22-2 event (1B)=(4)= Respondent located in 'Tsunami Danger Zone' at 3-6 event (1C)=(5)= Respondent located in 'Tsunami Danger Zone' at 23-12 event
9.1.	Aftershock Specification Question used to refer to the strongest event, as it is would be most similar to Sept. event.
9.2.	Parameter –Aftershock Perception Categorisation into ≥MMI6 Yes (1) = Criteria for evacuation fullfilled No (2) = Criteria for evacuation Not fullfilled
9.3.	Parameter – Aftershock Perception Categorisation depending on criteria at district level. Yes (1) = Criteria for Evacuation Fullfilled No (2) = Criteria for Evacuation Not Fullfilled
9.4.	Aftershock Response (1) = Not responded in terms of Tsunami Evacuation (2) = Evacuated from possible Tsunami (3) = Something Else
9.5.	Parameter – Behaviour Accordance (1) = Majority of people stayed in 'Tsunami Endangered Zone' (2) = Majority of people appeared to be evacuation from 'Tsunami Endangered Zone' (3) = Something else
10.	Parameter – Event Response Intension compared to 4-09 (1) = Behaviour change compared to 4-09 event (2) = No eehaviour change compared to 4-09 event
10.1	Parameter – Event Response Intension (1) = Respondent does Not intend to evacuate from possible tsunami, if earthquake occurs (2) = Respondent intends to evacuate from possible tsunami, if earthquake occurs
11.	Influence of tsunami sirens (1) = Tsunami sirens are already installed. (2) = Tsunami sirens will be installed.

	(3) = Tsunami sirens will not be installed. (4) = Respondent is not sure about the status of tsunami sirens in the area.
12.	Parameter – Hazard Knowledge Practical knowledge of sirens efficiency (1) = Respondent thinks that tsunami sirens safe lifes in the face of a local generated tsunami (2) = Respondent thinks that tsunami sirens do not safe lifes in the face of local generated tsunami, or et al.
12.1.	Parameter –Hazard Knowledge Practical knowledge of sirens efficiency (1) = Respondent knows to distinguish between local and regional/distant source tsunami. (2) = Respondent knows NOT to distinguish between local and regional/distant source tsunami.
12.1	Knowledge about Tsunami sirens (1)= Respondent knows about the existens/not existens of sirens used for the purpose of tsunami sirens used as a warning in his/her region (2)= Respondent knows Not about the existens/not existens of sirens used for the purpose of tsunami sirens used as a warning in his/her region
13.	Parameter – Overal Tsunami Risk Perception (1) = less than 10 years; (2) = less than 100 years; (3) = less than 500 years; (4) = less than 1,000 years; (5) = less than 5,000 years; (6) = less than 10,000 years (7) = less than 50,000 years; (8) = more than 50,000 years
14.	Likelihood of Tsunami for Respondent (1) = Tsunami will affect respondent (2) = Tsunami will Not affect respondent
15.	Parameter - Outcome Expectancy Level
16.	Parameter - Tsunami Risk Perception Level
17.	Parameter – Tsunami Preparedness (Self estimation) Level
18.	Parameter - Hazard Knowledge (Tsunami) Minutes
19.	Parameter – Hazard Preparedness 1 (1) = Respondent has a Get Away Kit (2) = Respondent does not have a Get Away Kit
19.1.	Parameter – Hazard Preparedness 2 Level
20.	Parameter – Hazard Preparedness (1) = Respondent has a Get Away Kit (2) = Respondent does not have a Get Away Kit
20.1.	Parameter – Actual Hazard Preparedness (1)= Respondent has a plan to meet household members in the case of an event. (2)= Repsondent does NOT have a plan to meet household members in the case of an event.
21.	Indicator - Nationality (1) New Zealander (2) English (3) Irish (4) Australian (5) United States

	(6) Germany (7) Japan (8) Finish (9) Frensh (1,2,3,4,6,8,9 = Nationalities with low hazard experience; 5,7= Nationalities with high hazard experience) Nationality: data is dependent on availability of data as tsunamis are defined as definite and therefore evidence of tsunami must exist. Further based on 100 years and a minimal death number of 10.
21.1.	Parameter- Event Experience (native country) Indicator - Nationality (cultural background)
21.2.	Parameter - Event Awareness (native country) Indicator - Nationality (cultural background)
21.3.	Parameter - Event Awareness (native country) Indicator - Nationality (cultural background)
22.	Parameter - Tsunami Experience (in New Zealand) (1) = Respondent experienced a tsunami in NZ (2) = Respondent did not experience a tsunami in NZ
23.	Parameter - Tsunami Awareness (in New Zealand) (1) = Respondent has heard about tsunami(s) in NZ (2) = Respondent did not hear about tsunami(s) in NZ
24.	Parameter - Disaster Awareness (in New Zealand) (1) = Respondent has experienced tsunami education in NZ (0) = Respondent has Not experienced tsunami education in NZ
25.	Parameter - Self Estimation of Tsunami Knowledge Level
26.	Parameter - Trust in Government Response to Disaster Level
27.	Parameter – Trust in Government Tsunami Information Level
28.	Indicator - Sex (1) = Male (2) = Female
29.	Indicator - Religiosity
30.	Indicator - Age Group K =(1) 18 to 20 O =(2) 21 to 25 P =(3) 26 to 30 S =(4) 31 to 35 T =(5) 36 to 40 W =(6) 41 to 45 E =(7) 46 to 50 L =(8) 51 to 55 D =(9) 56 to 60 H =(10) 61 to 65 Z =(11) 66 to 70 X =(12) 71 to 75 A =(13) 76 to 80 U =(14) 81 to 85 B =(15) 86 to 90 C =(16) 91 to 95 F =(17) 96 to 100 G =(18) ≥ 101
31.	Indicator - Income Group

	K=(1) $1 to $5,000 T=(2) $5,001 to $10,000 F=(3) $10,001 to $15,000 S=(4) $15,001 to $20,000 B=(5) $20,001 to $25,000 D=(6) $25,001 to $30,000 E=(7) $30,001 to $35,000 O=(8) $35,001 to $40,000 L=(9) $40,001 to $50,000 C=(10) $50,001 to $70,000 A=(11) $70,001 to $100,000 G=(12) $100,001 or more
32.	Indicator - Employment C =(1) Employed full-time O =(2) Employed part-time T =(3) Not in paid employment A=(4) Self-employed The employment groups are broken up in low (unemployed), medium (part-time), and high (full-time, self-employed).
33.	Indicator - Education K=(1) Did not complete High School A=(2) Completed High School T=(3) Trade / Polytechnic / Diploma S=(4) Undergraduate / Bachelors Degree W=(5) Postgraduate / Honours/ Masters / Doctorate Degree
34.	Indicator - Marital Status (1)= Single (2)= Living with Partner (3)= Married
35.	Indicator - Household Structure (1)= Respondent lives alone (2)= Respondent lives Not alone 1A=(3)= Respondent lives with Partner 1B=(4)= Respondent lives with Children 1C=(5)= Respondent lives with Parent(s) 1D=(6)=Respondent lives with Sibling(s) 1E=(7)= Respondent lives with Friend(s) 1F=(8)= Respondent lives with Other(s) The household structure is broken down in 3 Levels: Living alone, Living with partner or others, Living with Children.
36.	Indicator - Mobility (1)= Respondent holds a drivers licence

	(2)= Respondent does not hold a drivers licence
36.1.	Indicator - Mobility (1)= Respondent owns a registered car or motorbike (2)= Respondent does not own a registerd car or motorbike

APPENDIX 7: Nationalities categorisation according to tsunami hazard experience

Tsunami Events Search - sorted by Date, Country

Tsunami Events where (Year <= 2012 and Year >= 1912) and Deaths >= 10 and (Validity of Tsunami Occurence = 4) Tsunami Occurence >= 4)

Date			**Tsunami Source Location**				**Tsunami Parameters**				**Tsunami Effects**			
							Max Water Height	Num. of Runups	Magnitude	Tsu Int	Deaths #	Injuries #	Damage Mill. US$	Houses Destroyed #
1918	9	7	RUSSIA	S. KURIL ISLANDS	45.500	151.500	12.00	22	3.60	3.00	23	7		
1918	10	11	USA TERRITORY	PUERTO RICO: MONA PASSAGE	18.500	-67.500	6.10	21	2.60		142		4.000	
1922	11	11	CHILE	N. CHILE	-28.500	-70.000	9.00	35	3.20	2.50	200			
1923	4	13	RUSSIA	KAMCHATKA	56.500	162.500	20.00	11	4.90	3.50	18			
1923	9	1	JAPAN	SAGAMI BAY	35.100	139.500	13.00	103	3.60	3.00	2144	166		868
1928	8	4	INDONESIA	FLORES SEA	-8.320	121.708	10.00	2	3.30	3.00	128			
1929	11	18	CANADA	GRAND BANKS, NEWFOUNDLAND	44.690	-56.000	7.00	45	2.20		28		1.000	
1930	5	5	MYANMAR (BURMA)	MYANMAR COAST	17.300	96.500		1			500			
1930	12	23	PAPUA NEW GUINEA	BISMARCK SEA	-1.300	144.300	12.00	12	3.40	1.50	23			56
1931	10	3	SOLOMON ISLANDS	SAN CRISTOBAL ISLAND	-10.500	161.750	9.00	12	3.30	2.50	50			
1932	6	22	MEXICO	CENTRAL MEXICO	19.000	-104.500	10.00	6	3.30	1.50	75	100		
1933	3	2	JAPAN	SANRIKU	39.100	144.700	29.00	295	4.90	3.50	3022			6000

1934	4	7	NORWAY	TAFJORD	62.228	7.417	64.00	6			40			
1938	5	19	INDONESIA	MAKASSAR STRAIT	-1.000	120.000	3.00	6	1.60		17			
1940	8	1	JAPAN	W. HOKKAIDO ISLAND	44.200	139.500	3.50	53	1.80		10			20
1941	6	26	INDIA	ANDAMAN SEA, E. COAST INDIA	12.500	92.500	1.50	2			5000			
1944	12	7	JAPAN	OFF SOUTHEAST COAST KII PENINSULA	34.000	137.100	10.00	152	2.90	2.50	1223	2135		3059
1945	11	27	PAKISTAN	MAKRAN COAST	24.500	63.000	15.24	7	3.90		4000			
1946	4	1	USA	UNIMAK ISLAND, AK	53.320	-163.190	35.05	509	5.10	4.00	164		26.260	
1946	8	4	DOMINICAN REPUBLIC	NORTHEASTERN COAST	19.300	-68.900	5.00	8	2.20		1790			
1946	8	8	DOMINICAN REPUBLIC	NORTHEASTERN COAST	19.710	-69.510	.60	13			75			
1946	12	20	JAPAN	HONSHU: S COAST	33.000	135.600	6.60	298	2.70	2.00	1362			1451
1951	8	3	NICARAGUA	COSIGUINA VOLCANO	13.000	-87.500		1			1000			
1952	3	4	JAPAN	SE. HOKKAIDO ISLAND	42.150	143.850	6.50	219	2.70	2.00	33			
1952	11	4	RUSSIA	KAMCHATKA	52.750	159.500	18.00	290	4.20	4.00	4000		1.000	
1960	5	22	CHILE	CENTRAL CHILE	-39.500	-74.500	25.00	1045	4.60	4.00	1203		75.000	
1960	11	20	PERU	N. PERU	-6.800	-80.700	9.00	19	3.20	2.50	66	2	.550	
1964	3	28	USA	PRINCE WILLIAM SOUND, AK	61.040	-147.730	67.10	391	6.10	5.00	124		119.000	
1964	6	16	JAPAN	NW. HONSHU ISLAND	38.650	139.200	5.80	165	2.70	2.00	26	450	80.000	1960
1965	1	24	INDONESIA	SANANA ISLAND	-2.400	126.100		3	2.00	1.50	71			3000

1965	9	28	PHILIPPINES	TAAL, LUZON ISLAND	14.002	120.993	4.70	**1**			355			
1968	8	14	INDONESIA	BANDA SEA	.200	119.800	10.00	**7**	3.30	3.00	200	58		800
1969	2	23	INDONESIA	MAKASSAR STRAIT	-3.100	118.900	4.00	**5**	2.00	2.00	600			
1976	8	16	PHILIPPINES	MORO GULF	6.262	124.023	8.50	**30**	2.30	2.50	4376	5099	134.000	
1977	8	19	INDONESIA	SUNDA ISLANDS	-11.085	118.464	15.00	**15**	3.90	3.00	189	75	1.200	
1979	7	18	INDONESIA	LOMBLEN ISLAND [LEMBATA]	-8.600	123.500	9.00	**1**			1239	32		
1979	9	12	INDONESIA	IRIAN JAYA	-1.679	136.040	2.00	**2**	1.00		100			400
1979	12	12	COLOMBIA	COLUMBIA: OFF SHORE, PACIFIC OCEAN	1.598	-79.358	6.00	**53**	2.30	2.50	600	20000	8.000	10000
1983	5	26	JAPAN	NOSHIRO, JAPAN	40.462	139.102	14.93	**227**	3.90	2.00	100	324	800.000	3513
1992	9	2	NICARAGUA	NICARAGUA	11.742	-87.340	9.90	**36**	3.30	2.80	170	489	30.000	1500
1992	12	12	INDONESIA	FLORES SEA	-8.480	121.896	26.20	**25**	4.70	2.70	1169	500	100.000	31785
1993	7	12	JAPAN	SEA OF JAPAN	42.851	139.197	54.00	**184**	5.00	3.10	208	233	1207.000	2374
1994	6	2	INDONESIA	JAVA	-10.477	112.835	13.90	**24**	3.70	2.50	250	423	2.200	1500
1994	11	14	PHILIPPINES	PHILIPPINE ISLANDS	13.525	121.067	7.30	**21**	2.90	2.10	81	225	3.700	797
1995	5	14	INDONESIA	TIMOR SEA	-8.378	125.127	4.00	**2**	2.00	1.50	11	19		
1996	2	17	INDONESIA	IRIAN JAYA	-.891	136.952	7.68	**107**	2.90	1.80	110	100	4.200	
1996	2	21	PERU	N. PERU	-9.593	-79.587	5.10	**54**	2.30	1.90	12	57		15
1998	7	17	PAPUA NEW GUINEA	PAPUA NEW GUINEA	-2.961	141.926	15.03	**67**			2205	1000		
1999	8	17	TURKEY	KOCAELI, TURKEY	40.748	29.864	2.52	**18**			155			
2001	6	23	PERU	S. PERU	-16.265	-73.641	7.00	**106**			26			2000

2004	12	26	INDONESIA	OFF W. COAST OF SUMATRA	3.295	95.982	50.90	**1058**			226898		10000.000	
2005	3	28	INDONESIA	INDONESIA	2.085	97.108	3.00	**17**			10			
2006	7	17	INDONESIA	JAVA	-9.254	107.411	20.90	**196**			802	498	55.000	1623
2007	4	1	SOLOMON ISLANDS	SOLOMON ISLANDS	-8.460	157.044	12.10	**224**			52			2500
2007	4	21	CHILE	S. CHILE	-45.285	-72.606	7.60	**1**			10			
2009	9	29	SAMOA	SAMOA ISLANDS	-15.489	-172.095	22.35	**579**			192	7	275.000	
2010	2	27	CHILE	OFF SOUTHERN COAST	-36.122	-72.898	29.00	**579**			156	12000	30000.000	
2010	10	25	INDONESIA	SUMATRA	-3.487	100.082	7.00	**22**			431		39.000	700
2011	3	11	JAPAN	HONSHU ISLAND	38.297	142.373	38.90	**5776**			15854	5950	210000.000	121656

Reference:

NGDC/WDC (2012) **Global Historical Tsunami Database** [Internet], National Geophysical Data Center / World Data Center, Boulder, CO, USA. Available from <http://www.ngdc.noaa.gov/hazard/tsu_db.shtml> [Accessed 15th August 2012].

APPENDIX 8: Participant recruitment script for earthquake response questionnaire

PARTICIPANT RECRUITMENT SCRIPT

EARTHQUAKE RESPONSE QUESTIONNAIRE

University of Natural Resources and Applied Life Sciences, Vienna

Lincoln University Te Whare Wānaka o Aoraki

Hello my name is Matthias Dorfstaetter. I am studying at Lincoln University and, as part of my course of research I am conducting a questionnaire concerning the Canterbury Earthquakes. The findings from this study will be used to help local communities better prepare for hazards like earthquakes. Further this study will help to create more disaster resilient communities.

Could you spare around 15 minutes to answer some questions related to the 4th Sept. 2010 earthquakes and aftershocks?

- *[IF THE RESPONDENT SHOWS SIGNS OF STRONG EMOTION, BECAUSE OF MENTIONING THE EARTHQUAKES, INFORM HIM/HER THAT THIS ...???*
- *[IF NO, THEN THANK THE PERSON FOR THEIR TIME AND MOVE ON TO NEXT POTENTIAL PARTICIPANT.]*
- *[IF YES, GO TO NEXT SECTION.]*

Thank you for agreeing to participate. Before we begin I would need to know if you are in the target group of this study:

Are you over 18 years old?

- [IF YES, GO TO NEXT QUESTION.]

Were you located in the _________________ area when the 4th September earthquake hit?

- *[IF NO, THEN THANK THE PERSON FOR THEIR TIME AND MOVE ON TO NEXT POTENTIAL PARTICIPANT.]*
- *[IF YES, GO TO NEXT SECTION.]*

Thank you for agreeing to participate. Before we begin, I need to give you a bit more information.

- *[HAND OUT THE PARTICIPANT THE INFORMATION SHEET.]*

This research concerns your general perceptions during the earthquake and what you did immediately afterward. It also inquires about your level of hazard awareness and perception, and some personal data which will be aggregated to a group level to identify patterns in the population.

You have the right to withdraw from answering any or all questions at any time. The information you give me will remain anonymous – we don't ask for your name or any similar information – and all the data will be kept in a secure storage area. Only my supervisors and I will have access to the questionnaires. Any results from the study will be presented at the group level; no individual data will be used in any talks or publications.

If you have any questions about the research, please feel free to contact me or my Lincoln University supervisor. You can find our contact details on the Research Information Sheet.

Do you have any questions at this time?

- *[IF YES, THEN ANSWER AS FULLY AS POSSIBLE; THEN PROCEED TO THE QUESTIONNAIRE.]*
- *[IF NO, THEN PROCEED TO THE QUESTIONNAIRE, GO TO NEXT SECTION.]*

APPENDIX 9: Showcards for earthquake response questionniare

DEMOGRAPHIC GROUP CARDS

University of Natural Resources and Applied Life Sciences, Vienna

EARTHQUAKE RESPONSE QUESTIONNAIRE

Lincoln University

Showcard for **Employment-Group:**

[C] Employed full-time

[O] Employed part-time

[T] Not in paid employment

[A] Self-employed

Showcard for **Education-Group:**

[K] Did not complete High School

[A] Completed High School

[T] Trade / Polytechnic / Diploma

[S] Undergraduate / Bachelors Degree

[W] Postgraduate / Honours/ Masters / Doctorate Degree

Showcard for **Age-Group:**

K 18 to 20	O 21 to 25	P 26 to 30
S 31 to 35	T 36 to 40	W 41 to 45
E 46 to 50	L 51 to 55	D 56 to 60
H 61 to 65	Z 66 to 70	X 71 to 75
A 76 to 80	U 81 to 85	B 86 to 90
C 91 to 95	F 96 to 100	G ≥ 101

Showcard for **Income-Group:**

K $1 to $5,000	T $5,001 to $10,000	F $10,001 to $15,000
S $15,001 to $20,000	B $20,001 to $25,000	D $25,001 to $30,000
E $30,001 to $35,000	O $35,001 to $40,000	L $40,001 to $50,000
C $50,001 to $70,000	A $70,001 to $100,000	G $100,001 or more

APPENDIX 10:Modified Mercali Scale

The Modified Mercalli Intensity Scale

Simplified, from reference.

In New Zealand, where earthquakes occur from near the surface right down to a depth of over 600 km, the Modified Mercalli intensity scale is a better indicator of an earthquake's effects on people and their environment.

New Zealand scientists have modified it further to suit New Zealand conditions. It is used by many professionals who need to know the relationship between the strength of shaking at ground level and the degree of damage.

Category	Definition
MM 1: Imperceptible	Barely sensed only by a very few people.
MM 2: Scarcely felt	Felt only by a few people at rest in houses or on upper floors.
MM 3: Weak	Felt indoors as a light vibration. Hanging objects may swing slightly.
MM 4: Largely observed	Generally noticed indoors, but not outside, as a moderate vibration or jolt. Light sleepers may be awakened. Walls may creak, and glassware, crockery, doors or windows rattle.
MM 5: Strong	Generally felt outside and by almost everyone indoors. Most sleepers are awakened and a few people alarmed. Small objects are shifted or overturned, and pictures knock against the wall. Some glassware and crockery may break, and loosely secured doors may swing open and shut.
MM 6: Slightly damaging	Felt by all. People and animals are alarmed, and many run outside. Walking steadily is difficult. Furniture and appliances may move on smooth surfaces, and objects fall from walls and shelves. Glassware and crockery break. Slight non-structural damage to buildings may occur.
MM 7: Damaging	General alarm. People experience difficulty standing. Furniture and appliances are shifted. Substantial damage to fragile or unsecured objects. A few weak buildings are damaged.
MM 8: Heavily damaging	Alarm may approach panic. A few buildings are damaged and some weak buildings are destroyed.
MM 9: Destructive	Some buildings are damaged and many weak buildings are destroyed.
MM 10: Very destructive	Many buildings are damaged and most weak buildings are destroyed.
MM 11: Devastating	Most buildings are damaged and many buildings are destroyed.
MM 12: Completely devastating	All buildings are damaged and most buildings are destroyed.

Reference:

GNS (2012) **Modified Mercali Intensity Scale** [Internet], Geological and Nuclear Sciences Institute New Zealand. Available from <http://www.gns.cri.nz/Home/Learning/Science-Topics/Earthquakes/Monitoring-Earthquakes/Other-earthquake-questions/What-is-the-difference-between-Magnitude-and-Intensity/The-Modified-Mercalli-Intensity-Scale > [Accessed 18th June 2012].

APPENDIX 11:Overview of demographic data for study sites

Region	District	Area	Area code	Income	Averge Household Size	Average Age	House no.*
Canterbury	Waimakariri	Waikuku Beach	WIB	24.600	2,6	37	169
Canterbury	Waimakariri	Woodenend Beach	WOB	24.000	2,6	39,8	71
Canterbury	Waimakariri	Pines Beach	PIB	20.100	2,6	41	82
Canterbury	Christchurch City	Brooklands	BRO	24700	2,5	36	178
Canterbury	Christchurch City	North New Brighton	NNB	23.000	2,4	34	249
Canterbury	Christchurch City	New Brighton	NBN	20.500	2,2	35	311
Canterbury	Christchurch City	Southshore/South New Brigton	SOH	26.300	2,4	38	359
Canterbury	Christchurch City	Ferrymead	FEM	22.300	2,5	38	236
Canterbury	Christchurch City	Moncks Bay	MOB	31.000	2,5	45	246
Canterbury	Christchurch City	Sumner	SUM	29.800	2,5	38	285
Canterbury	Ashburton	Rakaia River Mouth	RRM	24.400	2,7	39,7	63
Canterbury	Ashburton	Hakatere	HAK	24.400	2,7	39,7	52
Canterbury	Ashburton	Rangitata River Mouth	RAR	24.400	2,7	39,7	65
Canterbury	Waimakariri District			24.000	2,6	39,7	
Canterbury	Ashburton District			24.400	2,7	39,8	
Canterbury	Christchurch City			23.400	2,5	36,4	
Canterbury				23500	2,5	36,4	

Official Data		Non-official Data	
based on:		based on:	
(green)	Area level[1]	(brown)	Personal Count
(orange)	District level[1]		
(purple)	Region level[1]		

* Contucted on the 1[st] of July 2012. Please note that these numbers presents an approximation to assign the participant approching time for each zone.
This data does not represent the actual household numbers.
Please note that deviations could arise form influencing conditions such as limitation of visability.
Houses are categorised abondoned and excluded from the zone,if they show major earthquake damage, and look abondoned, or are for sale.

References:

[1]Statistics New Zealand (2012) **Quick Stats About a Place** [Internet] New Zealand's National Statistical office. Available from <http://www.stats.govt.nz/Census/2006CensusHomePage/QuickStats/AboutAPlace.aspx> [Accessed 10th August 2012].