

THE SPATIAL AND TEMPORAL PATTERNS OF
ANXIETY AND CHEST PAIN RESULTING FROM THE
CANTERBURY EARTHQUAKES

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Abstract

The aim of this thesis was to examine the spatial and the temporal patterns of anxiety and chest pain resulting from the Canterbury, New Zealand earthquakes. Three research objectives were identified: examine any spatial or temporal clusters of anxiety and chest pain; examine the associations between anxiety, chest pain and damage to neighbourhood; and determine any statistically significant difference in counts of anxiety and chest pain after each earthquake or aftershock which resulted in severe damage. Measures of the extent of liquefaction and the location of CERA red-zones were used as proxy measures for earthquake damage. Cases of those who presented to Christchurch Public Hospital Emergency Department with either anxiety or chest pain between May 2010 and April 2012 were aggregated to the census area unit (CAU) level for analysis.

This thesis has taken a unique approach to examining the spatial and spatio-temporal variations of anxiety and chest pain after an earthquake and offers unique results. This is the first study of its kind to use a GIS approach when examining Canterbury specific earthquake damage and health variables at a CAU level after the earthquakes.

Through the use of spatio-temporal scan modelling, negative and linear regression modelling and temporal linear modelling with dummy variables this research was able to conclude there are significant spatial and temporal variations in anxiety and chest pain resulting from the earthquakes. The spatio-temporal scan modelling identified a hot cluster of both anxiety and chest pain within Christchurch at the same time the earthquakes occurred. The negative binomial model found liquefaction to be a stronger predictor of anxiety than the Canterbury Earthquake Recovery Authority's

(CERA) land zones. The linear regression model found chest pain to be positively associated with all measures of earthquake damage with the exception of being in the red-zone. The temporal modelling identified a significant increase in anxiety cases one month after a major earthquake, and chest pain cases spiked two weeks after an earthquake and gradually decreased over the following five weeks.

This research was limited by lack of control period data, limited measures of earthquake damage, ethical restrictions, and the need for population tracking data. The findings of this research will be useful in the planning and allocation of mental wellbeing resources should another similar event like the Canterbury Earthquakes occur in New Zealand.

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List of abbreviations

ASR	Age Standardized Rate
CAU	Census Area Unit
CDHB	Canterbury District Health Board
DHB	District Health Board
ED	Emergency Department
ESR	Environmental Science and Research
GIS	Geographic Information Science
MOH	Ministry of Health
NZDep	New Zealand Deprivation
PHO	Primary Health Organisation
PTSD	Post-Traumatic Stress Disorder
PWC	Population Weighted Centroid

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1.0 Introduction

1.1 Introduction

Christchurch, Canterbury is located on the east coast of New Zealand's South Island (Figure 1). Christchurch is the second largest city in New Zealand with a population of 348,435 as at the 2006 census (Statistics New Zealand, 2006).



Figure 1: Christchurch, New Zealand

On Saturday September 4, 2010 at 4:35am, a 7.1 magnitude earthquake, 10.5 kilometres deep struck Canterbury. The earthquake was centred 40 kilometres west of Christchurch city along the Greendale fault (Figure 1). No one was killed, however it caused wide spread damage to infrastructure and large amounts of liquefaction which resulted in further damage to infrastructure and resources. Since the September 4 earthquake, Canterbury has been struck by a series of aftershocks,

including on Tuesday February 22, 2011 at 12.51pm a 6.3 magnitude at a depth of 5.9 kilometres within 10km of Christchurch city which resulted in further damage, liquefaction and the death of 184 people, and many people were injured.

The Canterbury earthquakes have been linked to many negative health outcomes including initial physical injuries especially within the first 24 hours (Ardagh et al., 2012). The New Zealand Ministry of Health (MOH) commissioned Environmental Science and Research (ESR) to carry out research which would provide guidance for recovery should a similar event occur again in New Zealand; the liquefaction silt study found that liquefaction was of low risk to public health unless it had been contaminated by sewerage (ESR, 2012). As little time has passed since the last large earthquake and Canterbury is still experiencing aftershocks, there has been some delay in the publishing of health research. The media has reported increases in asthma and pneumonia due to the liquefaction which has yet to be removed, elderly people feeling lonely and isolated and an increase in men battling depression; although these findings are speculative and yet to be supported with evidence.

This thesis uses a Geographic Information Science (GIS) approach to analysing the spatial or temporal patterns that may have arisen as a result of these earthquakes.

1.2 New Zealand Context

The Canterbury region has a shallow ground water table and is situated on alluvial fans from rivers flowing east from the Southern Alps (Wotherspoon, Pender, & Orense, 2012). Both the Waimakariri, a large river located flowing from the Southern Alps to the ocean north of Christchurch and the Avon river, which runs through central Christchurch, has experienced substantial changes both naturally and man-made. Some suburbs to the east of Christchurch city are built on reclaimed river bed

and estuary. Liquefaction occurs when an earthquakes shaking causes the water table to build pressure and come up through the grounds surface taking silt and sand with it (Brackley, 2012). The geology of the region and the location of residential houses on reclaimed land makes the region highly susceptible to experience high levels of liquefaction (Brackley, 2012; Quigley, Bastin, & Bradley, 2013; Reid, Thompson, Irvine, & Laird, 2012; Villemure et al., 2012). After each of the September 2010, February 2011, June 2011 and December 2011 earthquakes, there was widespread liquefaction affecting thousands of properties. The liquefaction caused damage to resident's properties, transport networks, and contaminated the damaged storm water system (Brackley, 2012). Due to high winds in the days following an earthquake, the dry contaminated liquefaction was remobilised creating risk of long-term negative health outcomes (Villemure et al., 2012).

As a result of these earthquakes, the New Zealand Government initiated the Canterbury Earthquake Recovery Authority (CERA) who were placed with the responsibility of coordinating the on-going recovery effort following the earthquakes (CERA, 2011). Because of the extent of the damage to both residential and industrial areas across the region, CERA conducted assessments of the infrastructure and land, progressively assigning zones. These primary zones are listed below; however it is worth noting that at various times during the recovery process there has also been other technical zones within the categories.

1. Red Zone: Residential areas where an engineering solution to repair the land would be uncertain, costly and disruptive, or where cliffs and rock fall pose serious risk;

2. White Zone: Complex geotechnical issues relating to land slip and rock roll require further assessment;
3. Orange Zone: Engineers need to undergo further investigation;
4. Green Zone: Considered to be suitable for residential construction (CERA, 2011).

Prior to the February 22, 2011 Canterbury earthquake, the last earthquake which resulted in a large number of fatalities in New Zealand was the 1931 magnitude 7.8 earthquake in Napier where 256 people died (Eiby, 1968; Hancox, Perrin, & Dellow, 2002; Thomas, Cousins, Heron, Schmid, & Lukovic, 2006). Many of these deaths are believed to be as a result of fires which broke out across the city, and were unable to be controlled due to damage to water infrastructure (Thomas et al., 2006).

Given the rarity of an earthquake of this scale within New Zealand, the Canterbury earthquake in 2010 and subsequent aftershocks pose a unique opportunity to researchers. New Zealand is highly susceptible to large earthquakes due to its location along the Pacific and Australian tectonic plates (Figure 2) (H. Anderson, Webb, & Jackson, 1993; Stirling, Gerstenberger, Van Dissen, & Berryman, 2010; Walcott, 1978). Given the risk of earthquakes in New Zealand it is vital that all elements of the Canterbury earthquakes be examined, including any risks to health in order to be prepared should another earthquake occur.

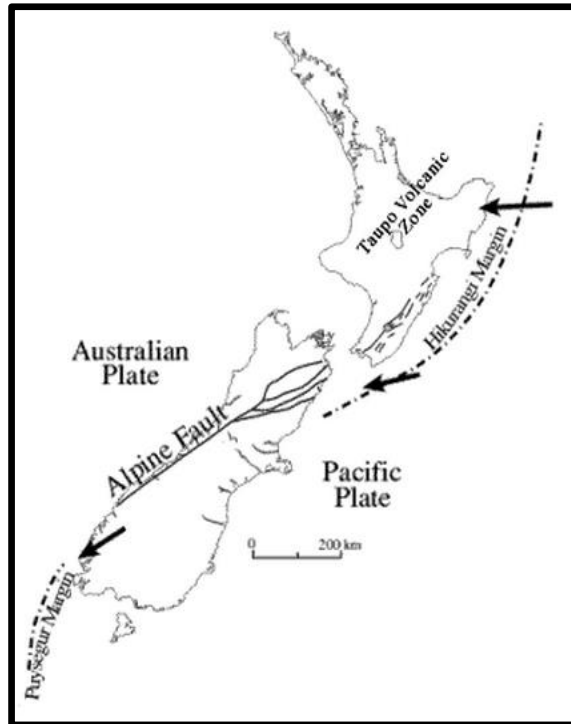


Figure 2: Location of Tectonic Plates (Toy, 2013)

1.3 Academic Context

The Canterbury earthquakes have had a large effect on public health in Canterbury. According to the doctrine of the World Health Organization, “health is a state of complete physical, mental and social wellbeing and not merely the absence of disease or infirmity” (WHO, 1994, p1). It is well cited within the academic literature that earthquakes can have a great influence on people’s health. The Canterbury earthquakes have been very well recorded as Canterbury has an extensive permanent seismograph network which allows for accurate data to be recorded (Bannister & Gledhill, 2012). Combining the characteristics of each earthquake and health is a unique opportunity for New Zealand researchers, and will enable greater understanding of the wider effects the earthquakes have had on Canterbury.

Earthquakes have been linked not only to initial physical injuries (Armenian, Melkonian, & Hovanesian, 1998; Chan, 2003; Ching-Hong, For-Wey, & Wang, 2004;

Leor, Kloner, & The, 1996; Malilay, 1995; Matsuoka et al., 2000; Peek-Asa, Kraus, Bourque, Vimalachandra, & Abrams, 1998); but they have also been linked to many long term negative health outcomes. For example, water-related communicable diseases, such as diarrhoea were high after the 2010 Haiti earthquake that is estimated to have killed 250,000 and injured 300,000 more (Walton & Ivers, 2011). The increase in such diseases after the Haiti earthquake has been linked to poor living conditions and over-crowding (Walton & Ivers, 2011). The 1976 Guatemala earthquake was associated with increases in measles, typhoid fever, typhus, anthrax, rabies, hepatitis and influenza (Spencer et al., 1977) although there is limited literature to support these outbreaks.

As well as physical illnesses after an earthquake, associations have also been found between earthquakes and mental wellbeing. For example, the existing literature highlights that earthquakes can cause an increase in anxiety and chest pain due to the stress associated with coping after an earthquake (Ching-Hong et al., 2004; Gold, Kane, Sotoodehnia, & Rea, 2007; Leor, Poole, & Kloner, 1996; Ogawa, Tsuji, Shiono, & Hisamichi, 2000; Watanabe, Okumura, Chiu, & Wakai, 2004).

1.4 Purpose

The primary purpose of this thesis is to understand the spatial and temporal patterns of anxiety and chest pain after the Canterbury earthquakes. This thesis focuses on the Canterbury District Health Board (CDHB) region to examine the spatial and temporal variation between Census Area Unit (CAU) for cases of anxiety and chest pain attendance at Christchurch Public Hospital Emergency Department (ED). This will provide knowledge of areas that required greater mental health resources and when to aid in reducing anxiety and chest pain resulting from the Canterbury earthquakes.

1.5 Aims and Objectives

The aim of this thesis is to examine the spatial and the temporal patterns of anxiety and chest pain resulting from the Canterbury earthquakes.

Three research objectives have been developed to meet the research aim:

1. Identify any spatial and temporal clusters of anxiety and chest pain;
2. Examine the association between anxiety, chest pain and damage to neighbourhood;
3. Determine any statistically significant difference in counts of anxiety and chest pain after each earthquake and aftershock which resulted in severe physical damage.

1.6 Thesis Structure

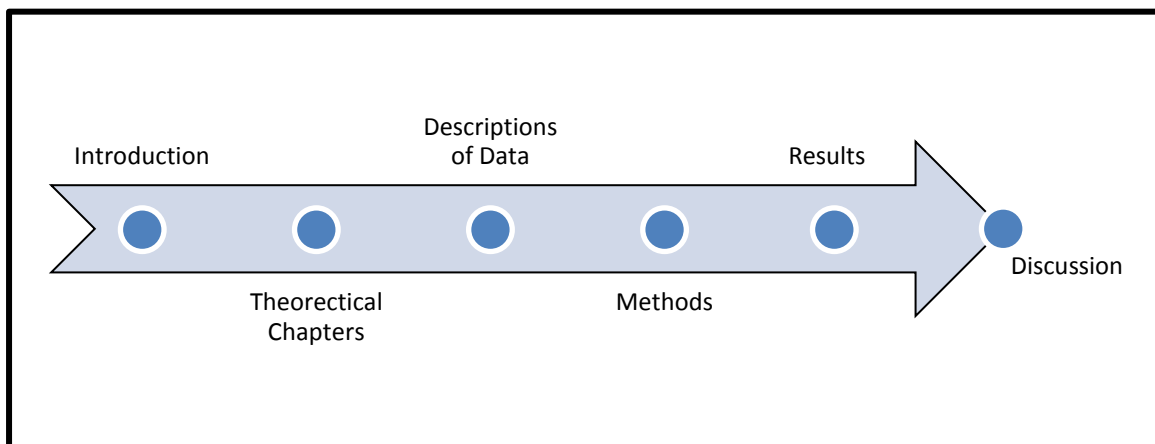


Figure 3: Thesis Structure

The introduction chapter provides an overview of what occurred in Christchurch in relation to the Canterbury earthquake and an introduction to the existing literature relating to health after an earthquake. This chapter also identifies the purpose, the aims and the objectives of this thesis as well as providing an overview of each chapter.

Chapter 2 gives the reader some insight into the existing literature on temporal and spatial patterns of health outcomes with a focus on anxiety and chest pain after an earthquake, as well as reviewing the methods that have been used.

Chapter 3 reviews the variables that the existing literature has previously identified as influencing anxiety and chest pain after an earthquake. This chapter also reviews the methods that have been used within the existing literature and how they controlled for these variables.

Chapter 4 provides an overview of each of the datasets used within this research. Not only does it outline the type of data but it also gives insight into why the data set was chosen as well as any limitations relating to the collection and use of the data.

Chapter 5 outlines the methods used within this thesis. It is broken into two sections to give an overview of the tasks involved within the data preparation as well as the methods used within the analysis and outlines why these methods were chosen. The analysis methods are broken down into three sections; and a description is provided of each of the research methods used.

Chapter 6 presents the results of this thesis. This chapter initially presents the results of analysing the individual data sets and presents some descriptive statistics and maps to help the reader understand the data. Chapter 6 then presents the results of the analysis of each research objective and clearly outlines any key findings.

Chapter 7 includes a discussion around the key findings from each objective and outlines how these objectives can be linked to the findings of the existing literature. This chapter also highlights the political implications of this research as well as any

research limitations and future research suggestions. This chapter is completed with a summary of this research and its primary findings.

2.0 Existing Literature Examining Spatial and Temporal Patterns of Negative Health Outcomes Post-Earthquake

2.1 Temporal

Within the literature on anxiety and chest pain related health outcomes after an earthquake, researchers have identified numerous temporal patterns. Initially after an earthquake health facilities need to be prepared for an increase in emergency patient visits. If an earthquake results in building collapse, the initial focus is the prompt evacuation of injured (Akbari, Farshad, & Asadi-Lari, 2004). Initially the most serious injuries include asphyxiation, internal haemorrhaging and intracranial injury (Chan, 2003; Liao et al., 2005). Salinas, Salinas, and Kurata (1998) used regression analysis to compare emergency department admissions from before and after the 1994 Northridge earthquake and found a threefold increase immediately after the earthquake. Salinas et al. (1998) results have been consistently supported by numerous other studies that have found an increase in hospital admissions especially with physical injuries immediately after an earthquake (H. K Armenian et al., 1998; Chan, 2003; Ching-Hong et al., 2004; Leor, Kloner, et al., 1996; Malilay, 1995; Matsuoka et al., 2000; Peek-Asa et al., 1998).

The time of day that an earthquake occurs can influence the severity of injuries and health outcomes. A review paper by Kloner (2006) summarized that earthquakes that occurred within the first three hours of people waking up, increased the likelihood of hypertension and heart disease. As well as the time of day influencing anxiety and chest pain related health outcomes, there is also evidence to suggest days of the week and seasonal patterns. For example, Bhattacharyya and Steptoe (2007) review of the existing literature on the emotional triggers of acute coronary syndromes found that studies have consistently identified Mondays and the winter season to have increased likelihood of acute coronary illness.

After the 1994 Northridge earthquake, Leor, Poole, et al. (1996) used chi-square and t-tests to examine 1952 deaths due to cardiac failure from before and after the earthquake, and found sudden death due to cardiac failure on the day of the earthquake increased by five times. Similar results to Leor, Poole, et al. (1996) have also been found following the 2001 Nisqually earthquake. Gold et al. (2007) used t-tests to compare death certificates for sudden cardiac arrest during the control periods and the week following the 2001 Nisqually earthquake. Gold et al. (2007) found a significant increase within only the first 48 hours, however not within the first week following the earthquake.

As well as examining the immediate patterns following an earthquake, researchers have also examined the temporal patterns in the weeks following an earthquake. Ogawa et al. (2000) examined 5470 death certificates of 16 municipalities and compared weekly standardized mortality rates from before and after the 1995 Kobe, Japan earthquake. Ogawa et al. (2000) found a significant increase in acute myocardial infarction for 8 weeks after the earthquake across the study region. The results presented by Ching-Hong et al. (2004) which examined admissions for acute myocardial infarction after the 1999 Taiwan earthquake, support Ogawa et al. (2000) and found a significant increase in admissions for six weeks after the earthquake.

The existing literature on the temporal patterns of chest pain and anxiety related health outcomes have also looked at the long term patterns. For example, H. K Armenian et al. (1998) found an increase in heart disease within the first six months following the 1998 earthquake in Armenia. Watanabe et al. (2004) longitudinal study after the 1999 Taiwan earthquake, interviewed 54 displaced Taiwanese adults, and found no difference in depressive symptoms between six and twelve months following the earthquake.

2.2 Spatial

The spatial relationships examining negative health outcomes after an earthquake have been reported widely by researchers. People who live in the most damaged neighbourhoods are often reported as having the highest number of physical injuries from an earthquake (H. K Armenian et al., 1998; Chan, 2003; Li et al., 2010; Malilay, 1995). Those who live in the most damaged neighbourhoods have also been reported as having the highest incidences of anxiety and chest pain related health outcomes (Ching-Hong et al., 2004; Eksi, 2009; Hsu, Chong, Yang, & Yen, 2002; P. Kun et al., 2009; Matsuoka et al., 2000; Ogawa et al., 2000; B. Wang et al., 2011; Xu & He, 2012)

The existing literature not only highlights positive relationships between neighbourhoods with the most physical damage after an earthquake having the highest incidence of anxiety and chest pain related health outcomes, they also report that there may be negative relationships where those in the most damaged neighbourhoods may be more resilient. After the 2008 Sichuan Province, China earthquake, Li et al. (2009) surveyed a convenience sample of 2262 adults on their concerns about safety and health after the earthquake. They compared the results between devastated and non-devastated areas using ANOVA to find that those in the most devastated areas reported less concern about safety and health after the earthquake than those in non-damaged areas. Li et al. (2009) hypothesised that a reason for this may be due to the 'Psychological Typhoon Eye' (Liang et al., 2008), where residents furthest from the most damaged areas had high estimation of post-earthquake concern. This was further supported in a sequential study, where the same patterns were found one year after the earthquake (Li et al., 2010).

Various methods have been used to explore the spatial patterns of anxiety and chest pain related health outcomes after an earthquake. For example, Ogawa et al. (2000) compared standardized mortality rates between regions after the 1995 Kobe, Japan earthquake. Ching-Hong et al. (2004) used Pearson Chi square analysis and odds ratios to compare between six different counties after the 1994, Northridge, California earthquake. Another frequent method for analysing the spatial patterns of anxiety and chest pain related health outcomes after an earthquake is to compare counts such as Li et al. (2009). Minami, Kawano, Ishimitsu, Yoshimi, and Takishita (1997) used categorical distance, within 50kilometers and between 50 to 60 kilometers from the earthquake epicentre, to examine the relationship between distance from earthquake epicentre and blood pressure.

This chapter has highlighted the need for spatial and temporal modelling after an earthquake. The existing literature has found variations in health outcomes due to their spatial location with respect to the earthquake epicentre. The existing literature also provides insight into the temporal patterns that can be expected after an earthquake but also highlights that these can vary between countries. This review of the existing literature reinforces the need for this thesis to be completed as it will add to the research gap especially within the New Zealand literature on health outcomes after an earthquake.

3.0 Factors Influencing Spatial and Temporal Patterns of Anxiety and Chest Pain Related Health Outcomes

Various factors have been identified to have an influence on anxiety and chest pain related health outcomes after an earthquake. This chapter reviews these variables and discusses methods that have been used to analyse these. These variables will need to be considered within any spatial or temporal analysis of anxiety or chest pain after an earthquake.

3.1 Age

One of the demographic variables that can influence the likelihood of suffering from a negative health outcome after an earthquake is age. After the 1994 Northridge earthquake, Peek-Asa et al. (1998) analysed earthquake related admissions at 78 hospitals in the Los Angeles County, and found that the number of injuries increased with age. Those aged 60-79 were 10.9 times more likely than those age 0-19 to sustain earthquake related injuries; and those aged 80 and above were 34.6 times more likely (Peek-Asa et al., 1998). This finding was supported by Knight, (2000) who interviewed 166 adults aged between 30 and 102 after the Northridge earthquake and found that those who were younger had less depressive symptoms (Knight, 2000).

The findings that age can influence negative health outcomes after an earthquake is further supported by research that has examined the health effects of earthquakes in other countries. For example after the 1999 Taiwan earthquake, asphyxiation and intracranial injury death was more prominent amongst the elderly (Chan, 2003), depressive symptoms were strongest among people aged 54-70 (Seplaki, Goldman, Weinstein, & Lin, 2006) and the elderly were more resilient than near elderly (Seplaki, Goldman, Weinstein, & Lin, 2006). After the 2008 Wenchuan, Sichuan Province, China earthquake, those in the age group 41-50 were severely affected by

the direct exposure (X. Wang et al., 2000), and those aged 35-44 had poorer health outcomes (Xu & He, 2012). After the 1998, New Castle, Australia earthquake, a longitudinal study found that morbidity persists in those who are older (Lewin, Carr, & Webster, 1998). In contraire to these studies, after the 1992 Cairo earthquake, those aged 5-14 had the highest earthquake related admissions to hospital; however this may have been due to a stampede at a school as a result of the earthquake (Malilay, 1995). A study conducted after the 1999 Taiwan earthquake examining the earthquakes implications on acute myocardial infarction found there to be no significant relationship between acute myocardial infarction and age (Ching-Hong et al., 2004).

There are numerous explanations as to why these relationships between age and health outcomes occur after an earthquake. These explanations highlight the importance of considering the influence age may have when conducting any research that examines the relationship between negative health outcomes and earthquakes. The maturation hypothesis (Knight, 2000), the inoculation hypothesis (Knight, 2000) and the burden perspective (Thompson, Norris, & Hanacek, 1993) are theories which help to explain why there may be variation in earthquake outcomes between age groups. The maturation hypothesis suggests that with age people have less emotional reactivity to stressful events as they have greater psychological maturity and improved coping styles (Knight, 2000). The inoculation hypothesis suggests that elderly people are more likely to have experienced similar traumatic events and therefore have less emotional reactivity (Knight, 2000). The burden prospective suggests that middle age adults feel they have greater responsibility to society and to their family and therefore experience poorer coping capacity (Thompson et al., 1993).

Various methods have been employed by researchers to account for age. A common method is to use age specific comparisons, for example Peek-Asa et al. (1998) used chi-square tests and odds ratios to compare age groups; Malilay (1995) modelled the time patients spend in hospital because of earthquake related injuries, and used linear regression models to predict length of stay between different age groups; Chan (2003) calculated standardized mortality rates for 16 different age groups; Ching-Hong et al. (2004) calculated counts from before and after the 1999 Taiwan earthquake for those aged >65 and <65 with acute myocardial infarction associated with the earthquake, and then compared these results using Pearson chi-square analysis.

Another method that has been utilised by researchers investigating health outcomes after earthquakes is to develop Age Standardized Rates (ASR). An example of where ASR have been used within health and earthquake research is after the 1995 Kobe, Japan earthquake. Matsuoka et al. (2000) calculated age and gender standardized morbidity rates for total illness and each illness leading to hospitalization, among the 14 areas. By calculating these ASR, Matsuoka et al. (2000) was able to conclude that there was no strong links between the extent of damage caused by the earthquake and morbidity, they were also able to rule out age or gender from influencing this conclusion.

3.2 Gender

The existing literature highlights there may be a variation in health outcomes after an earthquake between genders. Physical injuries after an earthquake have been found to be greater for females than males (Armenian, Melkonian, Noji, & Hovanesian, 1997; Bergiannaki, Psarros, Varsou, Paparrigopoulos, & Soldatos, 2003; Chan,

2003; Malilay, 1995). However in contraire some studies have found there to be no significant relationship between gender and physical injuries after an earthquake (P. Kun et al., 2009; Peek-Asa et al., 1998).

The existing literature has also examined the relationship between gender, anxiety and chest pain related health outcomes after an earthquake. (Armenian et al., 1998) found heart disease increased greater for males after the 1998 Armenian earthquake. Research has identified that more women than men suffer from anxiety related health outcomes which have been triggered by an earthquake (Richter & Flowers, 2008; C. L Seplaki et al., 2006; Suzuki et al., 1997; Zhang, Shi, Wang, & Liu, 2011). Zhang et al. (2011) conducted a cross-sectional survey of a temporary community set up after the 2008 Sichuan Province earthquake and used univariate and multivariate logistic regression analysis to identify potential risk factors. Zhang et al. (2011) identified the female gender as being one of the main risk factors for both post traumatic stress disorder (PTSD) and depression. In 2005, Yilmaz, Cangur, & Çelik) conducted a survey of earthquake victims of two cities in North-Western Turkey and found that first feelings after an earthquake change by sex difference. They found that women panicked 4.7 times more than men during an aftershock. Yilmaz et al. (2005) concludes that the women react more because of fear for their family rather than ignorance about earthquakes.

3.3 Accessibility of health resources

Another reoccurring theme highlighted within the literature is accessibility to health resources. Earthquakes often result in essential services being damaged. During the 2003 Iraq earthquake, the water supply; power; telephone; healthcare services; main roads; and the city's only airport were badly damaged (Akbari et al., 2004). As a result of the Sichuan Province earthquake in 2008 many essential services collapsed

resulting in an increase in vector borne diseases (P Kun et al., 2010). Research has found a strong positive correlation between building damage and injury / fatalities (Chan, 2003; Liao, 2005); however Peek-Asa, Ramirz, Shoaf, Seligson, and Kraus (2000) found only a weak relationship between building damage and fatality. Building damage and access to health services has been linked to PTSD and depression (Kilic, Aydin, & Taskintuna, 2008; Liaw, Wang, Huang, Chang, & Lee, 2008; Seplaki et al., 2006). Kilic et al. (2008) compared two areas affected by the 1999 Turkey earthquake, and found people who suffered psychological problems would by-pass a GP if they had access to other carers. Liaw et al. (2008) compared suicide rates as a result of the 1999 Taiwan earthquake, and found that areas that quickly started to re-build and had access to healthcare had lower suicide rates.

Earthquakes can result in people having to relocate; Caia, Ventimiglia, and Maass (2010) investigated whether type of temporary housing two years after an earthquake has an influence on psychological wellbeing and found that home attachment and satisfaction can encourage psychological wellbeing. Njord, Merrill, Njord, Lindsay, and Pachano (2010) found that people who have had to relocate to inappropriate environments often do not maintain good health-related behaviours and sometimes the move can lead to the development of worse behaviours. Health outcomes during an earthquake and the years following can be influenced by people's home environment as well as their access to medical facilities.

3.4 Socio-Economic Status

Socio-economic status has also been identified as a variable which can impact anxiety and chest pain related health outcomes after an earthquake. Ogawa et al. (2000) identified that a limitation of their findings related to mortality from acute myocardial infarction after the 1995 Kobe, Japan earthquake, was that they did not

consider socioeconomic status. Ogawa et al. (2000) recognised that socioeconomic status might influence the amount of damage to buildings, the recovery process and also residents access to medical care.

Education, location (urban or rural), and insurance are some of the indicators of socio-economic status which have been investigated to examine associations with health outcomes after an earthquake, especially after the 2008 Wenchuan, China earthquake. Xu and He (2012) had 2080 survivors from 19 counties complete a self-report psychological questionnaire after the 2008 Wenchuan, China earthquake. Xu and He (2012) used estimated regression models to identify coping factors associated with mental wellbeing after the earthquake, and found that having a higher socio-economic status had a positive effect on mental wellbeing after the earthquake. The finding that having higher education had a positive influence on the ability to cope after an earthquake, has been supported by B. Wang et al. (2011), where 430 households were surveyed after the earthquake, and analysed to examine the socioeconomic demographic characteristics on the rate of post-traumatic stress disorder (PTSD). Another study after the 2008 Wenchuan, China earthquake which surveyed 426 households in severely damaged and moderately damaged areas found that education, location and insurance were not associated with PTSD (P. Kun et al., 2009).

3.5 Ethnicity

Ethnicity has also been linked to being a variable that can influence incidence to anxiety and chest pain related health outcomes after an earthquake. After the 1994 Northridge, California earthquake, white, non-hispanic residents had the highest rates of injury, in comparison to African, Asian, and White Americans who had

significantly lower risk of injury resulting from the earthquake (Peek-Asa et al., 1998). This pattern reflects demography of the area closest to the earthquake epicentre.

After the 2008 Wenchuan, China earthquake, minority groups were reported to have the poorest health. Of the 2080 survivors from 19 counties interviewed, those of Qiang ethnicity had the lowest total health score, which supported that minority groups had poorer health than majority group ethnicity's (Xu & He, 2012).

Being of an ethnic minority may also improve coping strategies after an earthquake. Chadda, Malhotra, Kaw, Singh, and Sethi (2007) examined the mental health at 30 sites in different villages after the 2005 Kashmir, India earthquake. The local population had continuously been exposed to terrorism due to political conflict which often resulted in loss of property and constant sense of fear and apprehension in their daily lives. Because of this Chadda et al. (2007) hypothesised that the living conditions they were exposed to before the earthquake may have helped to improve their coping styles after the 6.8 magnitude earthquake.

Health outcomes as result of an earthquake may also be affected by migrant status. An Australian study on the 1989 Newcastle earthquake by Webster, McDonald, Lewin, and Carr (1995) interviewed 250 immigrants with non-English speaking backgrounds and 250 Australian born participants to explore the effects of a natural disaster on immigrants and host populations. Webster et al. (1995) found that non-English speaking migrants had an increased probability of suffering psychological distress.

3.6 Family

Injury and fatalities' within families appears to have connections to anxiety and chest pain related health outcomes after an earthquake. Those who had family members

injured can increase the likelihood of suffering from anxiety or chest pain related health outcomes (Hsu et al., 2002; P. Kun et al., 2009; B. Wang et al., 2011). More specifically, after the 2008 Wenchuan, China earthquake, those who were married were more likely to suffer from PTSD (B. Wang et al., 2011). A potential reason for the higher rates of PTSD in married survivors was due to them having greater concern about damage to their family members and possessions, especially as in China married people often still live together with their children and family (B. Wang et al., 2011).

4.0 Data Sources

This chapter discusses the various data sets used within this thesis as well as identification of any ethical consent that was obtained.

4.1 Area Data

4.1.1 NZ Cadastral Parcel Polygons/ Land Parcels

These are survey parcel polygons which identify the boundaries of property parcels. The data was collected and updated in 2011 by Land Information New Zealand (LINZ, 2012), and is made available to download as a shapefile in New Zealand Transverse Mercator projection by the providers of public geographic data, www.koordinates.co.nz, a free geographic data sharing website.

4.1.2 2006 Census Area Unit Boundaries

CAUs were chosen to represent the population who live within them as they are often a good measure of neighbourhood. A CAU is the second smallest unit of dissemination of census data in New Zealand, representing approximately 2,300 people. CAUs are an aggregation of finer meshblocks- which are the finest spatial level at which census data is disseminated. The CAU boundaries are updated following a Statistics New Zealand census, with the most recent available being 2006. A shapefile with polygons of each CAU boundaries for Christchurch is made available in New Zealand Transverse Mercator projection by www.koordinates.co.nz.

4.1.3 Canterbury District Health Board Boundary

The Canterbury District Health Board (CDHB) boundary is the focus region for this research. The CDHB is the second largest by population and by geographical area of the twenty District Health Board's (DHB) in New Zealand. The CDHB comprises of six territorial local authorities: Kaikoura, Hurunui, Waimakariri, Christchurch City, Selwyn and Ashburton (CDHB, 2013). Polygons for each of these territorial

authorities' boundaries were obtained from www.koordinates.co.nz and were aggregated together to create a polygon of the CDHB.

4.2 Primary Health Organisation Enrolment per CAU

Given the large population movement in Canterbury resulting from the earthquakes (Cubrinovski et al., 2011; Love, 2011) it is important to account for this within the analysis. A proxy population dataset was used which included quarterly enrolments to Primary Health Organisations (PHOs) by age group between February 2011 and July 2012. It is estimated 95.4% of those living within the CDHB region are enrolled in a PHO (Malcolm, 2010), therefore PHO enrolments were used as an estimate of population. For dates before February 2011, they were assigned the population count for February – April 2011 as it is believed that most of the population movement occurred after this date.

4.3 New Zealand Deprivation Scores

The New Zealand Deprivation Scores were collected from Statistics New Zealand based off the 2006 census (Statistics New Zealand, 2006). The scores are scaled to have a mean of 1000 index points and a standard deviation of 100 points (Salmond & Crampton, 2002; Salmond & Crampton, 2012). Various variables are used when calculating a deprivation score, including: income; employment; communication; transport; support; qualifications; living space; owned home. These scores for each CAU were retrieved from www.koordinates.co.nz.

4.4 Liquefaction

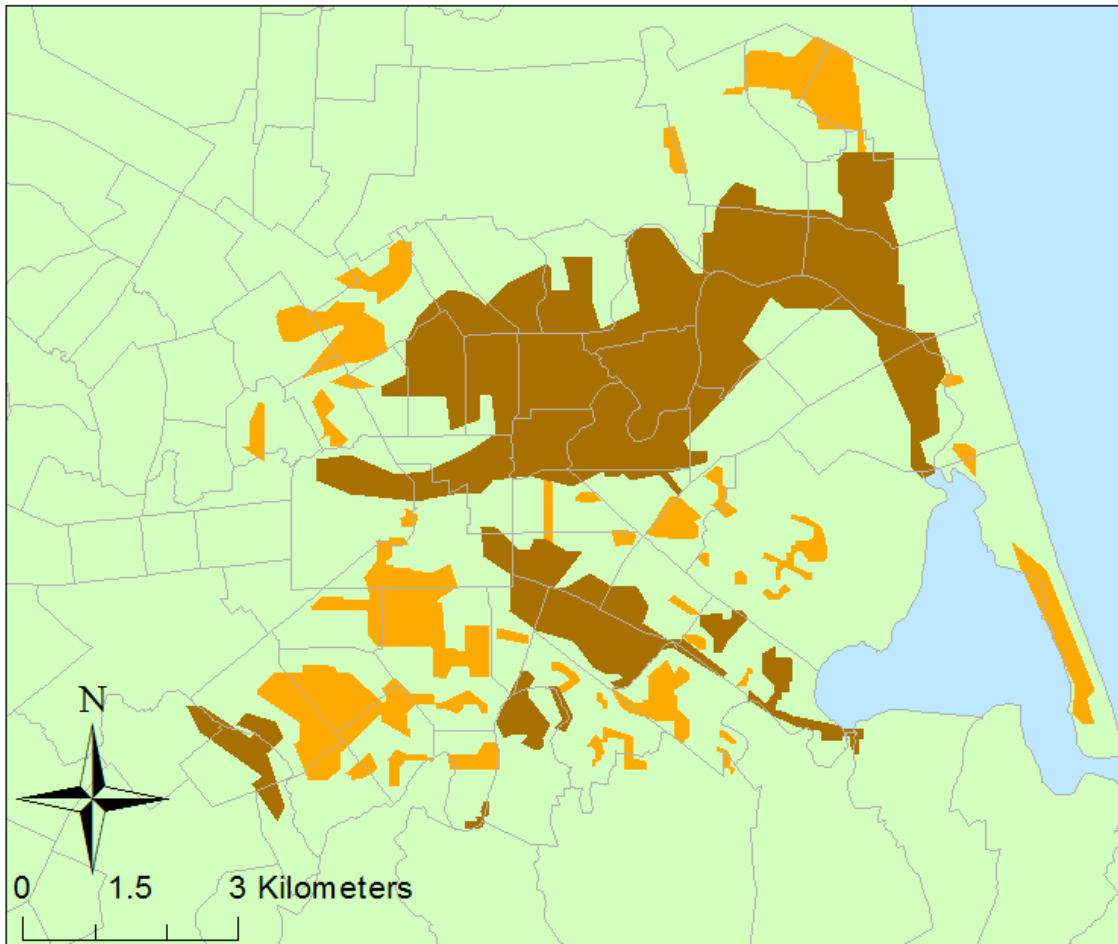
The liquefaction data was collected by researchers at the University of Canterbury with contributions from Auckland University and the Japanese Geological Society through the use of drive-through reconnaissance. The data was retrieved as a shapefile with polygons outlining the areas with either low to moderate or moderate

to severe liquefaction after the February 2011 earthquake in New Zealand Transverse Mercator Projection (Figure 4).



4.5 CERA Land Zones as at March 23, 2012

The CERA Land Zones as at March 23, 2012 was collected as polygons outlining the location of Red, Green, Orange and White zoned properties. The data was collected from North South GIS (NSG) as a shapefile in New Zealand Transverse Mercator Projection (Figure 5). As outlined in Chapter 1, the CERA land zones were continuously updated, this study has only focused on the land zones as of March 23, 2012 as they were the most recent at the time of data collection.

Extent of Liquefaction Resulting from February 2011 Earthquake



Extent of Liquefaction

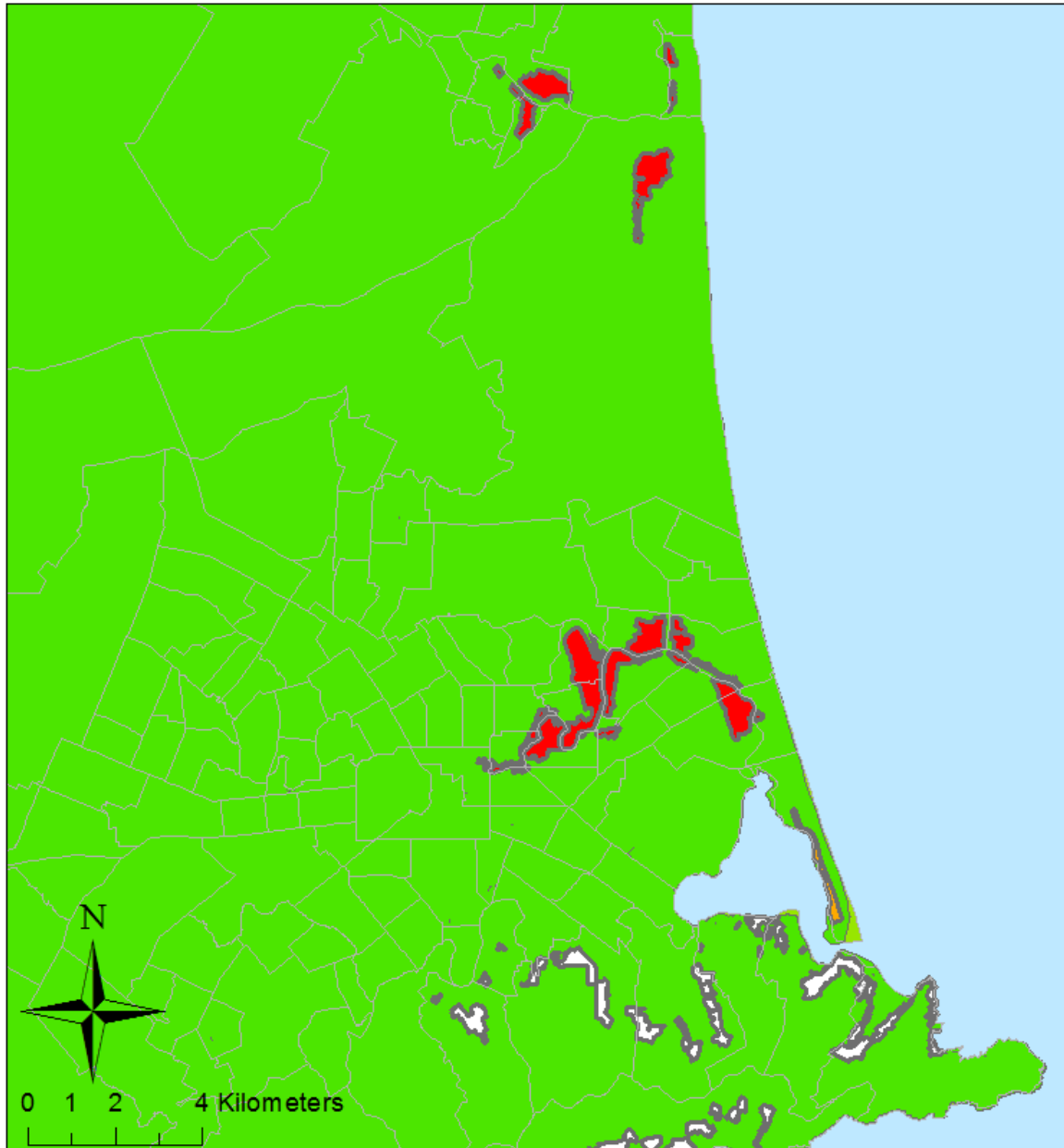
-  Low to Moderate
-  Moderate to Severe



Created by Kimberley Reed. 10-03-2013

Figure 4: Original Liquefaction Map

CERA Land Zones as of 23 March 2012



Green Zone Red Zone CDHB Region
Orange Zone White Zone

Data Source: Explorer Graphics Ltd
on Behalf of CERA

Created By Kimberley Reed; 10-03-2013



Figure 5: Initial Shapefile of CERA Land Zones as at 23/02/2012

4.6 Date of Major Earthquakes and Aftershocks

The dates and magnitudes of all earthquakes and aftershocks over a 4.0 magnitude within the Canterbury region were retrieved from www.geoet.co.nz as at April 30, 2012. This data was downloaded in Universal Time Coordinated (UTC) and then Microsoft Excel was used to convert to local time. Given the variation in shaking intensity, depth and location of the earthquakes it was not possible to use a quantitative approach in selecting the major earthquakes and aftershocks. Instead the five earthquakes that were known to have caused the most physical damage and which resulted in liquefaction were selected.

4.7 Christchurch Public Hospital Emergency Department Attendance for Anxiety between May 1, 2010 and April 30, 2012

This data was initially retrieved from RHISE on behalf of CDHB at a meshblock level. The data included arrival complaints for anxiety and stress to Christchurch Public Hospital's ED between May 1 2010 and April 30, 2012. It was only possible to obtain data from May 1, 2010 as previously this data was not recorded. The following fields were obtained for 524 cases: presentation date; patient age; patient gender; meshblock ID.

Given the low number of anxiety cases, this data was aggregated to CAU level for any analysis. Ethical consent was gained from RHISE on April 26, 2012 (Appendix 1) which enabled a request to be placed for anxiety data from the September 4, 2010. In order to gain data from before the first earthquake, ethical consent was obtained from the New Zealand Health and Disability Ethics Committee on November 16, 2012 (Appendix 2).

4.8 Christchurch Public Hospital Emergency Department Attendance for Chest Pain between May 1, 2010 and April 30, 2012

Data was sourced through the RHISE database on behalf of the CDHB for all presentations to Christchurch Public Hospital (CPH) Emergency Department (ED) for Chest Pain between May 1, 2010 and April 30 2012. The following fields were gathered: ED presentation date, patient age at event; patient gender; CAU code.

Given this research is focussed on the CDHB region, CAUs that are not within the focus area were removed as were those that the geocoder was unable to find a match for. The total number of presentations to CPH by people who listed their address as one that falls inside of this research focus area for Chest pain between May 1, 2010 and April 30, 2012 was 9807. Of the 9807 cases, 45.5% were female with a combined mean age of 61.

Ethical consent was gained through both the RHISE group on April 26, 2012 and the New Zealand Health and Disability Ethics Committee on November 16, 2012 to use this data, see Appendix 1 and Appendix 2.

4.9 Claims to ACC for Mental Injury as a Result of a Physical Injury or Mental Injury due to Work.

A data request was placed for all work related mental injuries and mental injuries caused by physical injury for all cases within the CDHB region from ACC. Ethical consent was given by the ACC ethics committee on September 10, 2012 (Appendix 3) to access this data. However, after receiving this data it was decided to exclude it from further analysis as there were only 316 cases between May 1, 2010 and April 30, 2012 and only included people of working age.

5.0 Methods

The methods used can be broken down into two key phases; Data Preparation Analysis which was then followed by the Research Analysis. These key phases can then be broken down further as outlined in Figure 6. Various software packages were used within the data preparation and analysis, including ESRI ArcGIS, Microsoft Excel, STATA, SPSS 19 and SaTScan.

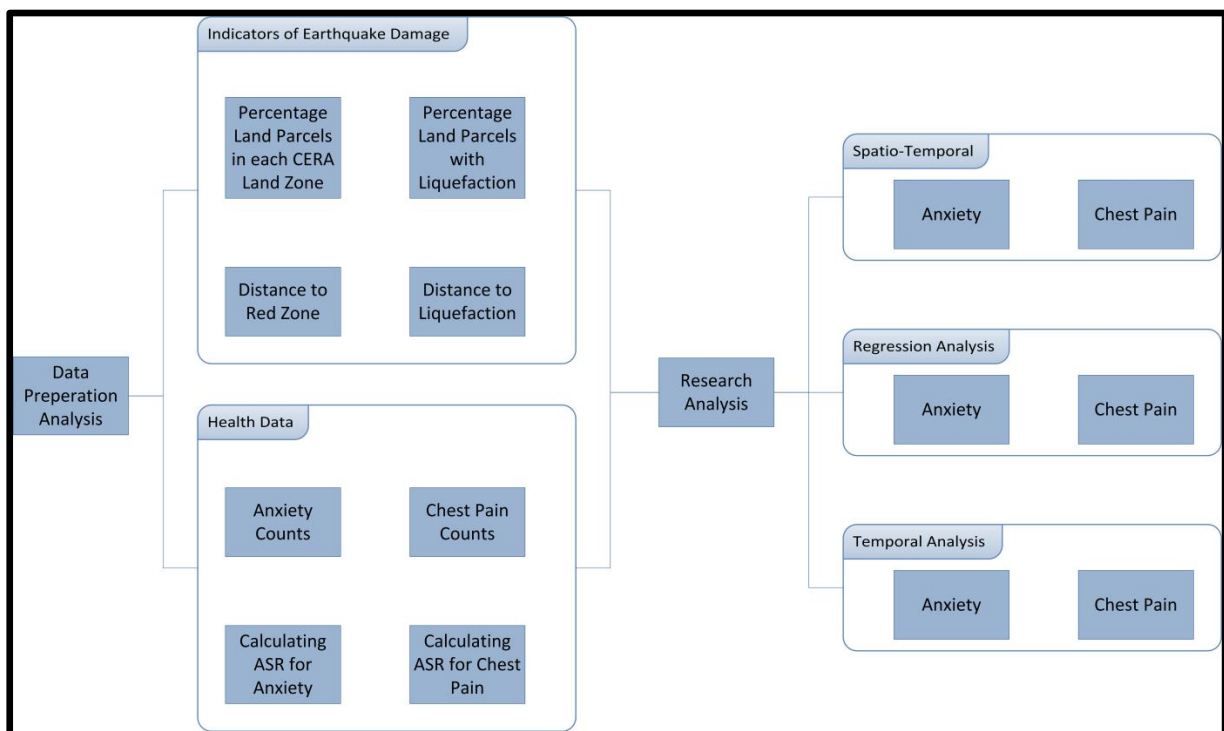


Figure 6: Key Data Preparation Analysis and Research Phases

5.1 Data Preparation Analysis

Before any analysis could be undertaken, a series of data preparation tasks ranging from geocoding addresses to calculating Age Standardized Rates were undertaken. Outlined below is an overview of the steps involved within the data preparation analysis.

5.1.1 CERA Land-Zones

Within ArcMap 10 a model was created to identify which CAU the CERA land zones were in. The CERA land zones are polygons which cross over the boundaries of the CAUs therefore it was necessary to clip the CERA land zones to land parcels. To calculate the percentage of land parcels zoned either Red, Green, Orange or White three layers were used: CERA Land Zone polygons; polygons of 2006 CAUs; and polygons of land property parcels. ArcMap Model Builder was used to develop a workflow where the CERA land zones were joined based on the spatial location to the land parcels; these were then converted to points which were then joined to the CAUs (Figure 7). The model resulted in the attribute table including information outlining which CAU each property parcel is in as well as what its land zone is. This attribute table was exported to Excel where the number of property's zoned Green, Red, Orange and White was calculated using the Pivot Table function within Excel. The final output was a table including the CAU ID, the age group, the date and the counts for each.

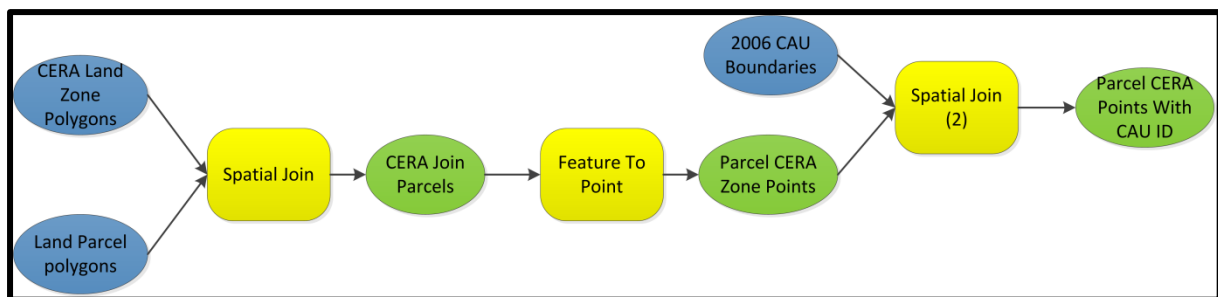


Figure 7: Example of the Model for Identifying CERA Zones within a CAU

5.2.2 Calculating Percentage of CAU with liquefaction

The percentage of Land Parcels within each CAU with liquefaction was calculated following the same steps as for percentage of land parcels within each CAU with a CERA land zone.

5.2.3 Calculating Euclidean Distance to Liquefaction and Red Zone from CAU Population Weighted Centroid (PWC)

Within the existing literature on spatial patterns of anxiety and chest pain related health outcomes and earthquakes some studies used distance as their spatial variable. Minami et al. (1997) for example compared blood pressure of those who lived within 50 kilometres of the 1995 Kobe, Japan earthquake epicentre compared to greater than 50 kilometres. The method sections are very limited in discussing how they calculated distance. There are two primary measures of distance, euclidean straight line and shortest path via a road network (Jones, Ashby, Momin, & Naidoo, 2009). The existing literature does not discuss how they calculated distance; Jones et al. (2009) compared the two measures of distance for insurance health care research and found little difference, however they did highlight the importance of acknowledging which measure has been used. Given the damage of roads, and on-going road repairs within Christchurch, Euclidean straight line was selected as the most appropriate measure of distance for this research.

The measure of distance needed to be representative of the CAU, the two primary options for this was calculating the distance from the geographic centre of the CAU or the population weighted centre of the CAU. Sharkey and Horel (2008) examined the spatial accessibility of food in a rural area, and identify that if a study area has CAUs which can cover a large area then the use of PWC's may be the best measure. The PWC of each CAU was calculated based off the geographic centre of each land property parcel coordinates in ArcMap10. New fields were added into the attribute table to identify the X and the Y coordinates of each land property parcel, these values were averaged for each CAU to find the coordinates of the PWC for each CAU.

Within ArcMap10, the 'Near' tool was used to calculate the Euclidean distance from the population weighted centroid of each CAU to the nearest polygon with liquefaction and to red zone.

Given the expected large variation in distance to liquefaction and red zone because of large size of the study focus region and the small centralized locations of red zones and liquefaction, quintiles were calculated. Of the existing literature that has used measures of distance, the preferred option is to use categorical measures (Minami et al., 1997). As well as calculating the Euclidean distance to liquefaction and to red zone in metres, quintiles for distance to liquefaction and quintiles for distance to red zone were calculated in Microsoft Excel using the 'PERCENTILE()' function. A choropleth map showing the locations of each quintile for both distance to liquefaction and distance to red zone was also created within ArcMap10 to visually present the geographic location of each of the quintiles.

5.2.3 Geocoding Anxiety Data and Calculating Counts for Anxiety

Geocoding is the process of assigning a description of a location such as addresses to a spatial location on the earth's surface. Often it is not possible to have the geocoder correctly identify all of the addresses; Ratcliffe (2004) analysed what an acceptable geocoding hit rate is within crime research, and found that a 85% address match to be acceptable. There are various reasons why an address may not match including; an address may be incorrectly recorded, for example there may be a misspelled street name; or the address may be correctly recorded however it may be assigned the wrong geocode such as wrong census area unit identifier (Krieger, Waterman, Lemieux, Zierler, & Hogan, 2001).

The anxiety data is stored by the Canterbury District Health Board at address level. As the initial research intention was to have a large enough data set to use data at a meshblock level, a data request was placed for the data to be converted from address level to meshblock level. Due to ethical issues, the geocoding was completed by the Canterbury District Health Boards Data Analysts. They used the Critchlow and Associates geocoder (Critchlow, 2013) and matched the address to the Statistic New Zealand's 2006 meshblock boundaries. Of the initial 657 addresses put through the geocoder, 37 addresses were unable to be matched. The 37 addresses that were not matched by the geocoder were manually checked, of which seven were unable to be corrected for the geocoder to match. Some of the reasons why the geocoder initially was unable to match the addresses included; miss spelling of the street name, name of the building given instead of street number, wrong suburb name and the address was spelt wrong. The addresses that were not able to be matched using the geocoder or manually was due to; no street number being provided, incorrect address given and no fixed abode.

Within Microsoft Excel, the data was coded for both monthly and quarterly as well as coded based on one of four age groups and the excel function 'pivot table' was used to calculate the count of cases within each date and age group. The 'pivot table' function was also used to calculate the number of anxiety within each CAU per month and per quarter.

5.2.4 Calculating Counts for Chest Pain

The chest pain data collected from Christchurch District Health Board had already been pre-assigned a field which identified the CAU the patient lived within at the time they presented to Christchurch Public Hospital's Emergency Department. The chest pain data was coded for weekly, monthly and for quarterly to match the dates of the

population, and the age groups were coded also based on the population data age groups. Using the Excel function 'pivot table' the counts of attendance to Christchurch Public Hospital emergency department were calculated for weekly, monthly and quarterly intervals. As with the anxiety data, counts were also calculated as a total per time period, and as a total for each CAU within each time and age group.

5.2.5 Calculating Age Standardized Rates for Anxiety and Chest Pain

The use of standardized rates when comparing variables is a common method within health research (Anderson, Le Riche, & MacKay, 1969; Carr et al., 1997; Chan, 2003; Ogawa et al., 2000; Willett et al., 1987).

As outlined in section 3.1, the known effects of age on health after an earthquake; there have been numerous studies which have found positive associations between age and negative health outcomes after an earthquake (Chan, 2003; Knight, 2000; Lewin et al., 1998; Peek-Asa et al., 1998; Seplaki et al., 2006; X. Wang et al., 2000; Xu & He, 2012). Like Matsuoka et al. (2000) who controlled for age when comparing earthquake damage after the 1994 Kobe, Japan earthquake and morbidity; ASR for anxiety and for chest pain have been calculated. By using the ASR's when completing the analysis it will be possible to eliminate age as a variable which may have influenced the results.

Direct ASR for each CAU per 100,000 people were calculated for both Anxiety and Chest Pain, using the PHO enrolment data as base population and New Zealand 2006 Census Population data as the standard population. Because the PHO enrolment data was only from April 2011, dates before that were assumed to have the same population as April 2011. As well as calculating ASR quarterly, it was also

calculated based on the total counts of anxiety and chest pain over the study period using the April 2011 PHO enrolment data as population and New Zealand 2006 Census Population data as the standard population.

To calculate ASR for anxiety of those aged between 0 and 14 using the direct standardization method, the count of anxiety of those aged between 0 and 14 in the CAU is divided by the PHO population in CAU within that 0 to 14 age group, and then multiplied by the percentage of people who are aged between 0 to 14 in New Zealand based on the 2006 census results. This is calculated for each age group, and then they are summed together and expressed per 100,000. The same method was followed for calculating chest pain ASR for each CAU.

5.3 Analysis

Each of the three research questions involved the use of different analysis techniques. For question one, which examined spatio-temporal clusters of anxiety and chest pain, SatScan was used to explore purely spatial, purely temporal and space-time clusters of anxiety and chest pain. The second question which investigated the associations between anxiety, chest pain and damage to neighbourhood was examined with linear regression and negative binomial models. The final question used dummy variables within linear regression analysis to explore temporal differences in counts of anxiety and chest pain after each earthquake. The remainder of this chapter will discuss the methods used for each of the three research questions.

5.3.1 Spatio-temporal clusters of anxiety and chest pain

The review in Chapter 2 and 3 of the existing literature on anxiety and chest pain after an earthquake highlighted the need for spatial-temporal analysis. Given the lack of existing literature on spatio-temporal clusters of anxiety and chest pain resulting

from an earthquake, a review of methods used for spatio-temporal cluster modelling in wider health research was conducted. Space-time models can be done from both a prospective (Kulldorff, Heffernan, Hartman, Assunção, & Mostashari, 2005) and a retrospective view (Bailony et al., 2011; Dietz et al., 2011; Pardhan-Ali et al., 2012; Westercamp et al., 2010). Kulldorff et al. (2005) used a Poisson and Bernoulli-based prospective space-time scan statistic model within SaTScan to analyse the prospective space-time permutation scan statistic for early detection of disease outbreaks with the use of case numbers only, instead of also including population-at-risk data. Kulldorff et al. (2005) finds the space-time permutation scan statistic which is calculated in SaTScan to be an important tool in early disease detection. Pardhan-Ali et al. (2012) used a set of scan tests in SaTScan to detect high or low rates of notifiable gastrointestinal illness at both a temporal and spatial level. The spatial scan statistic used by Pardhan-Ali et al. (2012) was a maximum likelihood ratio test statistic based on a circular window, using counts of notifiable gastrointestinal illness at various time periods and health units based off the geographic centroid of each health unit.

For both the anxiety and chest pain counts within each CAU between May 1, 2010 and April 30, 2012, the following models within SaTScan were run.

1. Retrospective Purely Spatial controlling for age and deprivation
2. Retrospective Purely Temporal controlling for age and deprivation
3. Retrospective Space-Time controlling for age and deprivation

The first retrospective purely spatial model used a Poisson discrete scan statistic to scan for areas with either high or low rates of anxiety also known as hot or cold spots. The analysis controlled for four age groups, 0-14, 15-39, 40-64 and 65 and

over and also controlled for deprivation using NZDep scores, time precision was set to generic with 8 time periods to represent each quarter. The spatial scan window used a circular spatial window shape with a maximum spatial cluster size as 50 percent of the population at risk, and the maximum number of Monte Carlo replications was set to 999. The same settings were used for the purely spatial chest pain analysis.

The retrospective temporal model for anxiety focussed on quarterly counts of anxiety for each CAU between 1 May 2010 and 30 April 2012. The model also controlled for age and deprivation. The retrospective purely temporal model used a Poisson discrete statistic to scan for high or low rates, with time precision set to a generic eight periods. The maximum temporal cluster size was set to 50 percent of the study period, with a default p-value of 0.05 and a maximum number of Monte Carlo replications of 999. These same settings were used to run the retrospective temporal model for chest pain.

The retrospective space-time model for anxiety focussed on the quarterly counts of anxiety for each CAU between 1 May 2010 and 30 April 2012. The retrospective space-time model used a Poisson discrete scan statistic to scan for high or low rates over the eight time periods. The maximum spatial cluster size was set to 50 percent of the population at risk, and a circular spatial window shape was selected. The maximum temporal cluster size was set to 50 percent of the study period. The default P-value selected was 0.05 and a maximum number of 999 Monte Carlo Replications were allowed.

The outputs for each of these models gave a list of the CAUs within each of the identified significant hot and cold clusters, as well as a relative risk and log likelihood

ratio. The results from the purely spatial and space-time models for anxiety and chest pain have also been displayed on a map created in Esri ArcMap software to visually show the geographic locations of the clusters.

5.3.2 Associations between anxiety, chest pain and damage to neighbourhood

The existing literature highlights the strength in regression modelling when comparing the effect the damage to a neighbourhood had on health outcomes. Regression modelling is a commonly used method for comparing methods, and has often been used when analysing the relationships between health outcomes and measures of earthquake damage (Leor, Poole, et al., 1996; Malilay, 1995; Matsuoka et al., 2000; Salinas et al., 1998; Xu & He, 2012; Zhang et al., 2011).

Anxiety

In order to choose a suitable regression model to examine the association between anxiety and damage to neighbourhood; the distribution of total anxiety counts between May 1, 2010 and April 30, 2012 was examined through the creation of a frequency histogram in SPSS and also the calculation of the mean and variance. Given the low number of total cases, and the high number of CAU's which had zero cases of anxiety; a likelihood ratio test for the over-dispersion parameter alpha was calculated to confirm the dependent variable is over dispersed therefore a negative binomial model would be best.

Using the total counts of anxiety per CAU between 1 May 2010 and 30 April 2012, PHO enrolment data for each CAU, NZDep scores and the measures of earthquake damage; various negative binomial models were created within Stata- a data analysis and statistical software program. Each independent variable was added

separately to the model, and with the addition of a new variable a likelihood ratio test was used to see if the addition of the variable improved the model fit. This process was repeated multiple times until a model was created that was able to best predict anxiety.

Chest Pain

To determine the best regression model for examining the relationship between chest pain and earthquake damage the distribution of total chest pain ASR between 1 May 2010 and 30 April 2012, were examined using a frequency histogram created in SPSS 19. As a result of examining the distribution of ASR, a linear regression model was chosen; and any outlier CAUs were removed from future analysis. Linear relationships between chest pain ASR and the independent variables were examined using scatter plots and the calculation of Pearson correlations. Any independent variables that did not have a significant linear relationship with chest pain counts were removed from further analysis.

Multiple linear regression models were run adding various combinations of independent variables whilst controlling for deprivation. The linear regression models were created in SPSS, and the output included 95% confidence intervals, model fit, descriptive, part and partial correlations, collinearity diagnostics and residual casewise diagnostics. The strongest model was selected based off the strength of all output variables.

5.3.3 Temporal relationship between when an earthquake occurred and when people presented with anxiety or chest pain

Various methods within the existing literature have been used to examine temporal patterns of health outcomes after an earthquake. A common method is to use statistical analysis to compare control periods to a set time frame after an

earthquake (Gold et al., 2007; Leor, Poole, et al., 1996; Ogawa et al., 2000). Given the uniqueness of the Canterbury earthquakes and the frequency and intensity of aftershocks a unique approach within the existing literature on temporal patterns after an earthquake was used. Linear regression within SPSS was used with dummy variables to identify the expected number of cases of anxiety for the month of an earthquake and one month after; and at weekly intervals for eight weeks for chest pain counts.

6.0 Results

In order to analyse the three research questions identified in chapter 1, analysis of the key data sets was completed which then aided the more specific analysis that focused on the research objectives. The research objectives identified in chapter 1 are:

1. Identify any spatial and temporal clusters of anxiety and chest pain;
2. Examine the association between anxiety, chest pain and damage to neighbourhood;
3. Determine any statistically significant difference in counts of anxiety and chest pain after each earthquake and aftershock which resulted in severe physical damage.

This chapter firstly examines the data sets: CERA land zones, liquefaction, anxiety and chest pain. Following from this the chapter presents the results of the three research objectives.

6.1 Examining Key Data Sets

6.1.1 CERA Land Zones

Within each CAU an average of 2.8% (sd = 10.4) of land parcels were zoned red and 85.2% (sd = 31.9%) of land parcels were zoned green on March 23, 2012 (Table 1). Table 1 also shows the percentage of land parcels zoned orange and white, however because these land zones are not a focus of this research they will not be discussed any further. This large variation in the number of land parcels within the red and green zone is further highlighted in Figure 8. A majority of land parcels are zoned all green, however one CAU has 67% of its land parcels zoned Red.

Table 1: Descriptive Statistics of CERA Land Zones

	Mean	SD	Minimum	Maximum	N
Green (%) Per CAU	85.2	31.9	0	100	187
Red (%) Per CAU	2.8	10.4	0	67	187
Orange (%) Per CAU	0.1	1.8	0	23.7	187
White (%) Per CAU	0.9	4.5	0	32	187
Distance (m) from CAU PWC Red Zone	18186.6	27440.2	0	139087.8	187

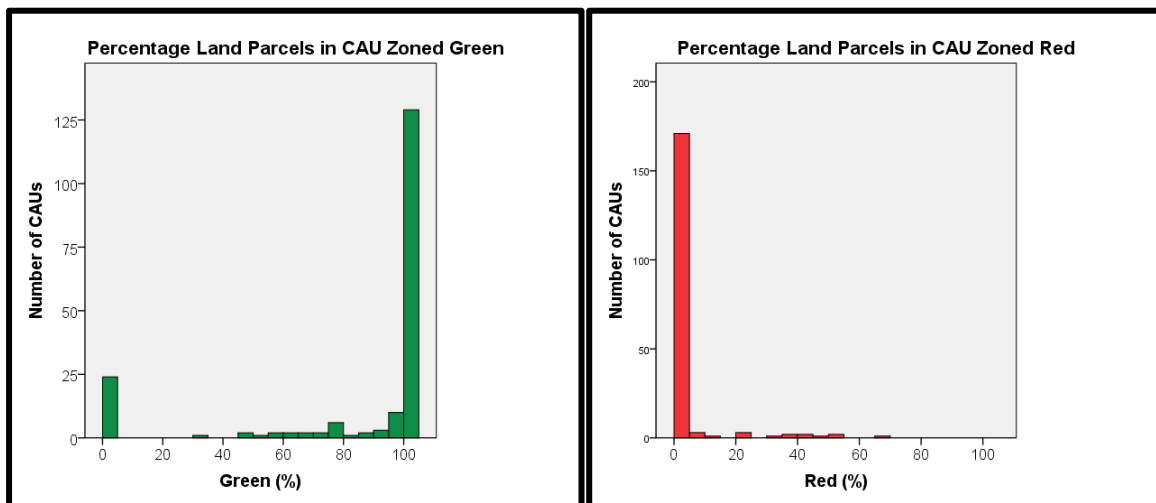


Figure 8: Histograms showing percentage Land Parcels in Green and Red Zones

The distance from the CAU population weighted centroid to the nearest area of red zone was also calculated. As shown in Table 1 on average CAUs were 18.2km from red zone with a standard deviation of 27.4km. This indicates a large variation in the distance to red zone, and is further re-enforced in Figure 9 which shows most CAUs were within 25km of a red-zone, however there was a maximum distance of 139.1km.

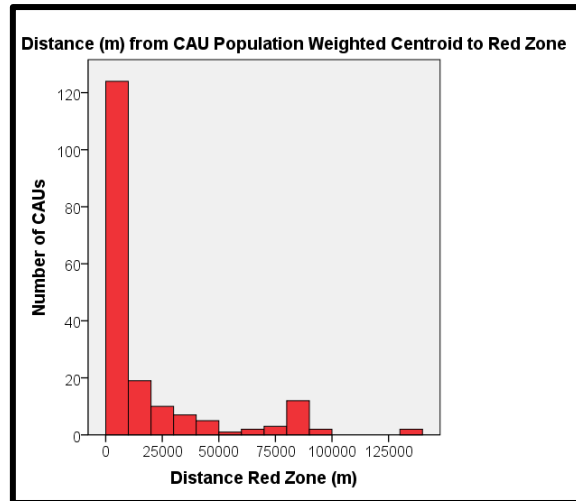


Figure 9: Histogram Distance to Red Zone

The distance from CAU Population Weighted Centroid (PWC) to red zone quintiles was also calculated and mapped (Figure 10). Quintile 1 which is the closest 25% of CAUs is restricted to being close to Christchurch city and Kaiapoi and then the further from the city the further the distance to red zone.

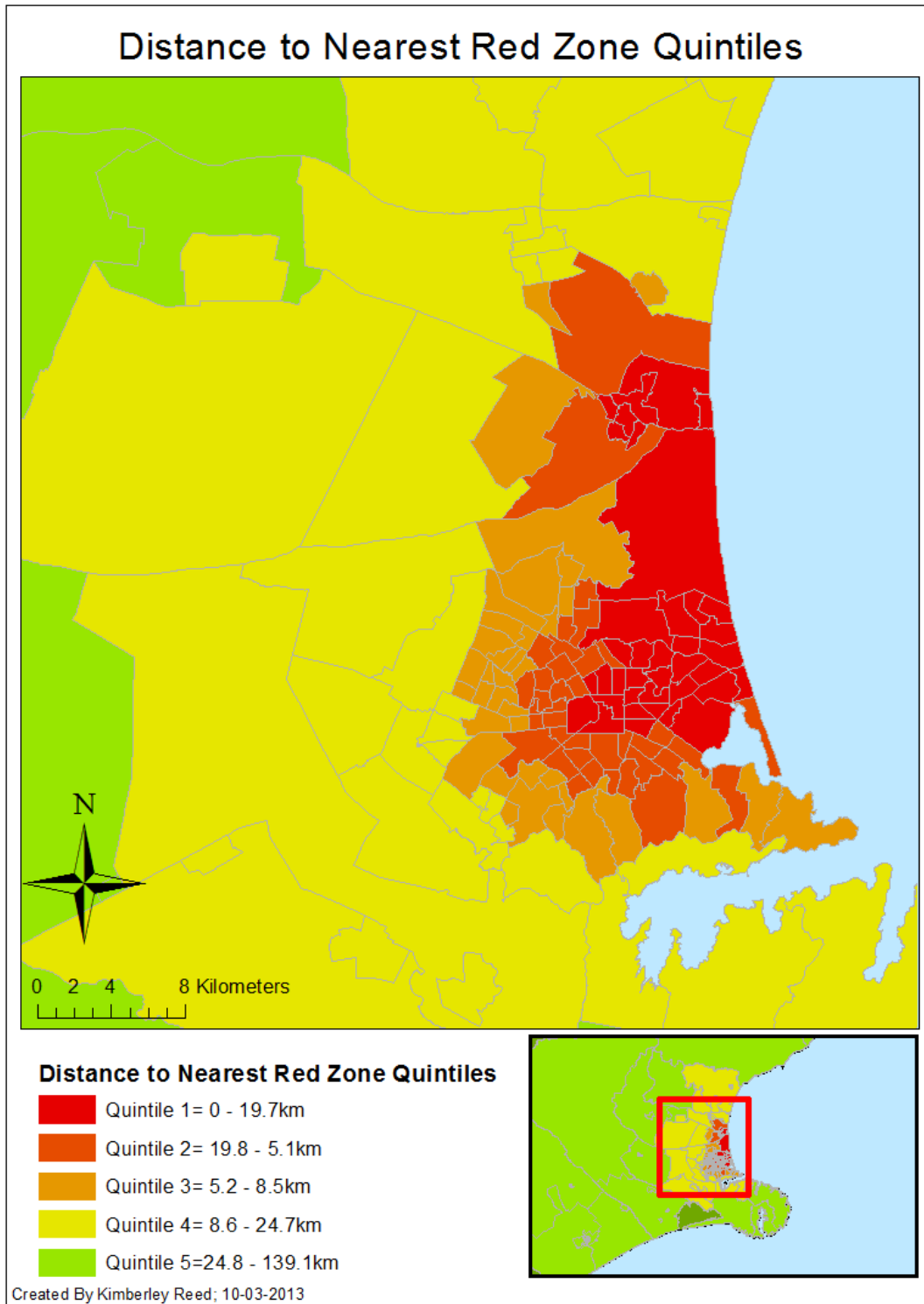


Figure 10: Distance to Red Zone Quintiles

6.1.2 Liquefaction

The majority of CAUs in the CDHB had no liquefaction (Figure 4). Table 2 shows there was a lot of variation in the amount of liquefaction a CAU had, with some CAUs having up to 95.9% of land parcels with liquefaction. The high standard deviation values and large differences between minimum and maximum liquefaction suggest there is large variation in how much liquefaction there was between CAUs, this is further shown in Figure 11 which shows the distribution of liquefaction.

On average, the CAU population weighted centroid was 17.2km from liquefaction, with a standard deviation of 28.4km. The histogram of distance to liquefaction (Figure 12) highlights that a majority of CAUs are within 20km of liquefaction. Given the large variation in distance to liquefaction, quintiles have also been calculated (Figure 13). 20% of CAUs were within 0.1km of liquefaction, and 40% of CAUs were within 1.8km of liquefaction. Both quintile 1 and quintile 2 are located close to Christchurch city, with the distance to liquefaction increasing the further away from Christchurch city the CAU is.

Table 2: Descriptive Statistics of Liquefaction

	Mean	SD	Minimum	Maximum	N
Low to Medium (%)	4.4	12.2	0	59.6	187
Moderate to Severe (%)	7.9	19.3	0	95.9	187
Distance (m) from CAU PWC to Liquefaction	17236.6	28355.1	0	147788.3	187

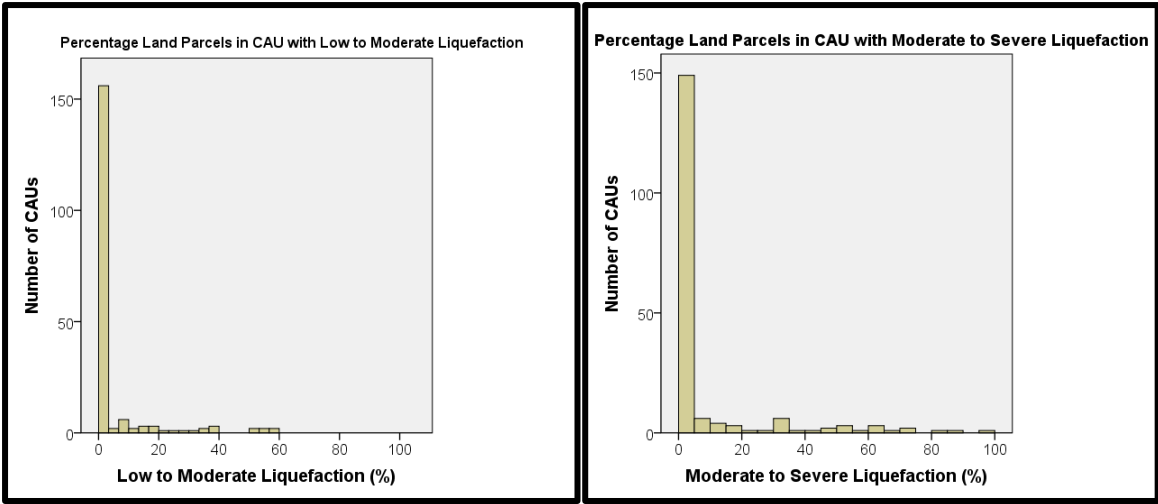


Figure 11: Histograms Showing Distribution of Liquefaction in CAUs

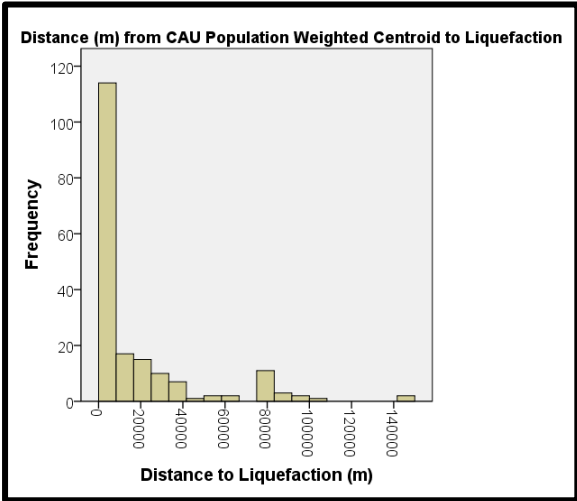


Figure 12: Histogram Distance to Liquefaction

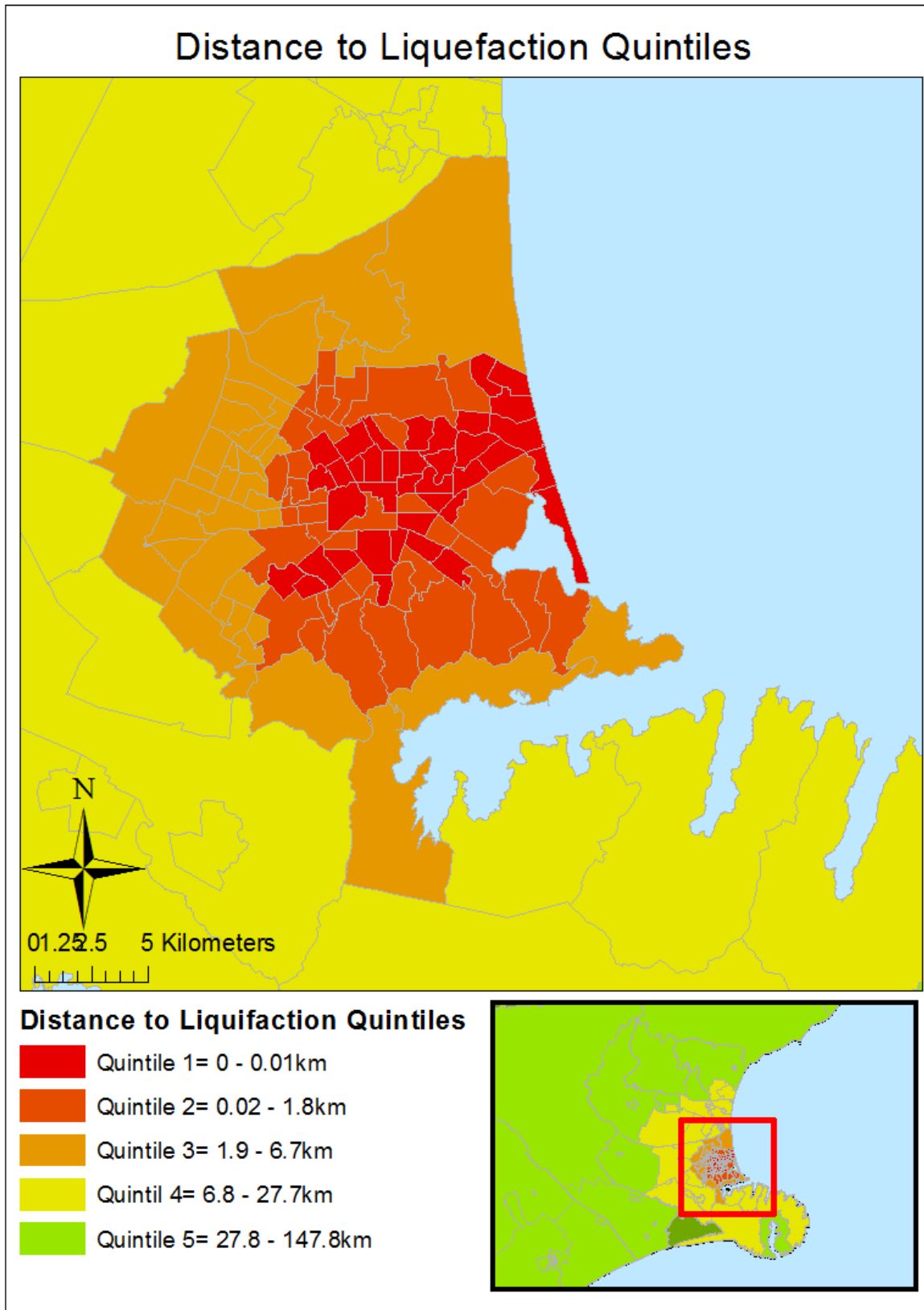


Figure 13: Distance to Liquefaction Quintiles

6.1.3 Anxiety

Counts of anxiety for each month between May 2010 and April 2012 were calculated. Figure 14 highlights the variation in anxiety between months, with September 2010, November 2010 and March 2011 having the highest counts of anxiety. Table 3 shows that on average there was 21 cases of anxiety each month, with a standard deviation of 9 which indicates a large variation in anxiety counts between months.

Table 3: Descriptive Statistics Anxiety

	Mean	SD	Minimum	Maximum	N
Anxiety Counts (Monthly)	21.8	9.0	9 (June 2010)	42 (November 2010)	24
Anxiety Counts (Per CAU)	2.8	3.5	0	23	187
Anxiety ASR (Per CAU)	102.2	116.9	0	718.9	187

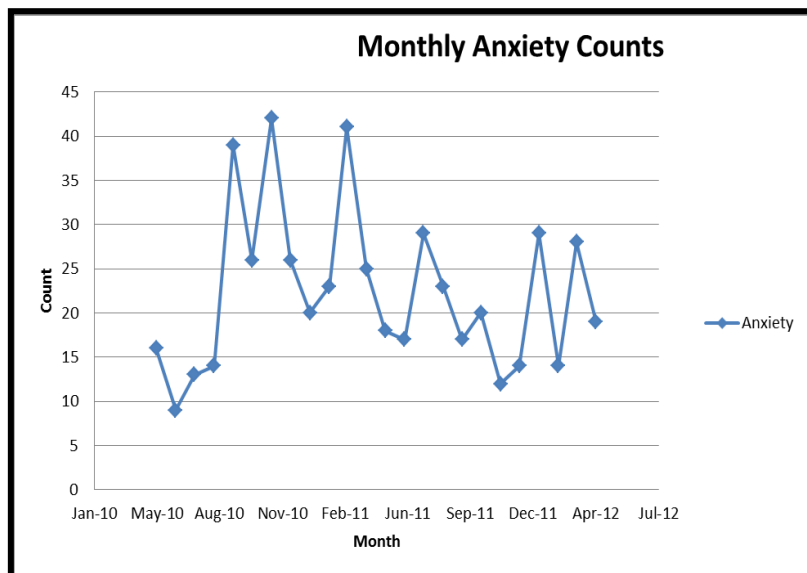


Figure 14: Graph of Monthly Anxiety Counts

Anxiety counts were also calculated as a total for each CAU between May 2010 and April 2012 (Figure 15). The descriptive statistics results (Table 3) show that on average 2.8 cases of anxiety were reported per CAU with a standard deviation of 3.5 which indicates that most CAUs had low anxiety counts however there are potentially CAUs which may be outliers.

Age Standardized Rates (ASR) per 100,000 people was also calculated for each CAU between May 2010 and April 2012 (Figure 16). The ASR highlight similar CAUs as the counts in Figure 8, however CAUs to the north of the city around Kaiapoi are highlighted with high ASR. The descriptive statistics in Table 3 show that on average there were 102 cases of anxiety per 100,000 people within a CAU with a standard deviation of 116.9. This indicates that there was large variation in ASR between the CAUs, and again there is a large difference between the minimum ASR and maximum which indicates there may be outliers.

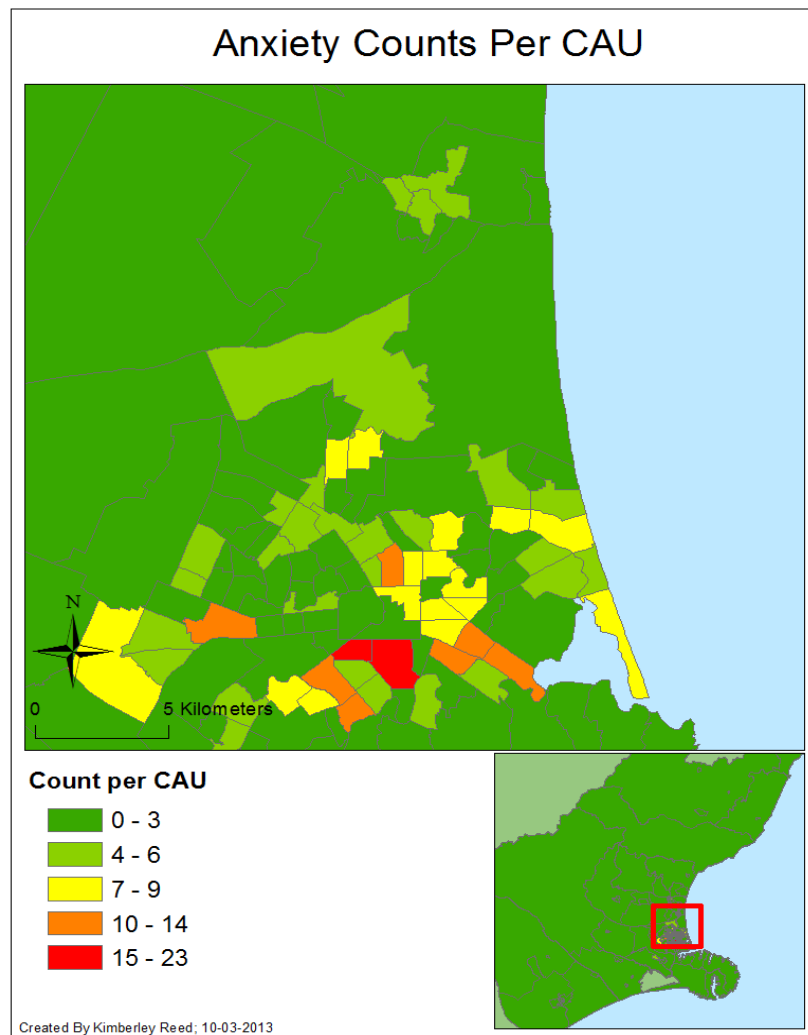


Figure 15: Anxiety Counts

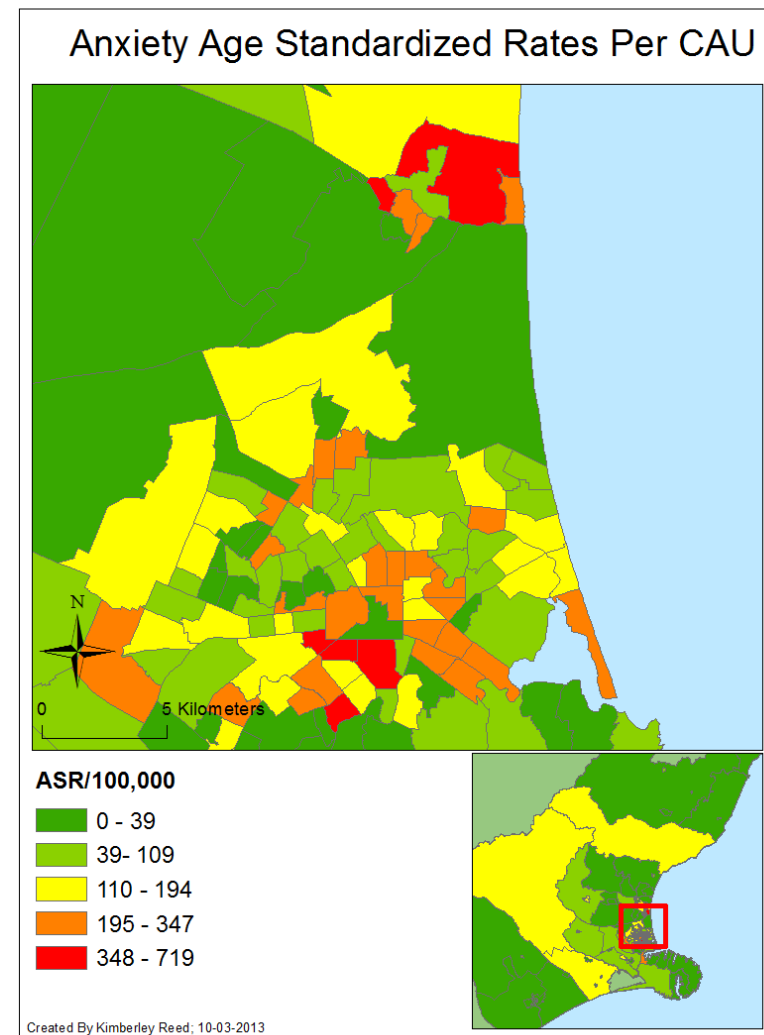


Figure 16: Anxiety ASR

6.1.4 Chest Pain

The descriptive statistics for chest pain counts at monthly intervals (Table 4) show that on average there were 96 cases of chest pain per week (408 per month) between May 2010 and April 2012 with a standard deviation of 15.8 (51.7 for monthly) indicating there was some variation in the chest pain counts. Monthly counts are also shown in Figure 17 which shows a peak in chest pain counts between August 2010 and October 2010.

The results shown in Table 4 indicate a large variation in both chest pain counts and chest pain ASR between CAUs. The variation in chest pain counts per CAU and chest pain ASR are shown in Figures 19 and 20. A visual interpretation of Figures 18 and 19 do not show any obvious patterns other than that the areas with high chest pain counts and high chest pain ASR are located close to Christchurch city.

Table 4: Descriptive Statistics Chest Pain

	Mean	SD	Minimum	Maximum	N
Chest Pain Counts (Weekly)	96.5	15.8	67	149	104
Chest Pain Counts (Monthly)	408.6	51.7	329 (August 2011)	545 (September 2010)	24
Chest Pain Counts (Per CAU)	52.4	40.2	0	181	187
Chest Pain ASR (Per CAU)	1968.4	1292.1	0	13888.7	187

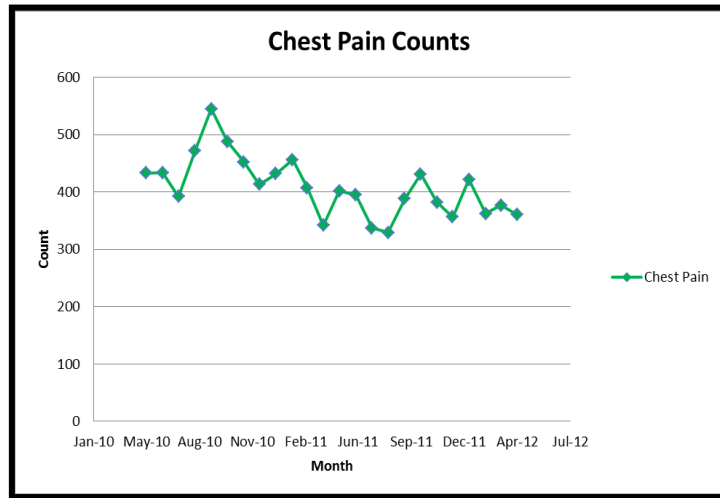


Figure 17: Line Graph Chest Pain Counts Monthly

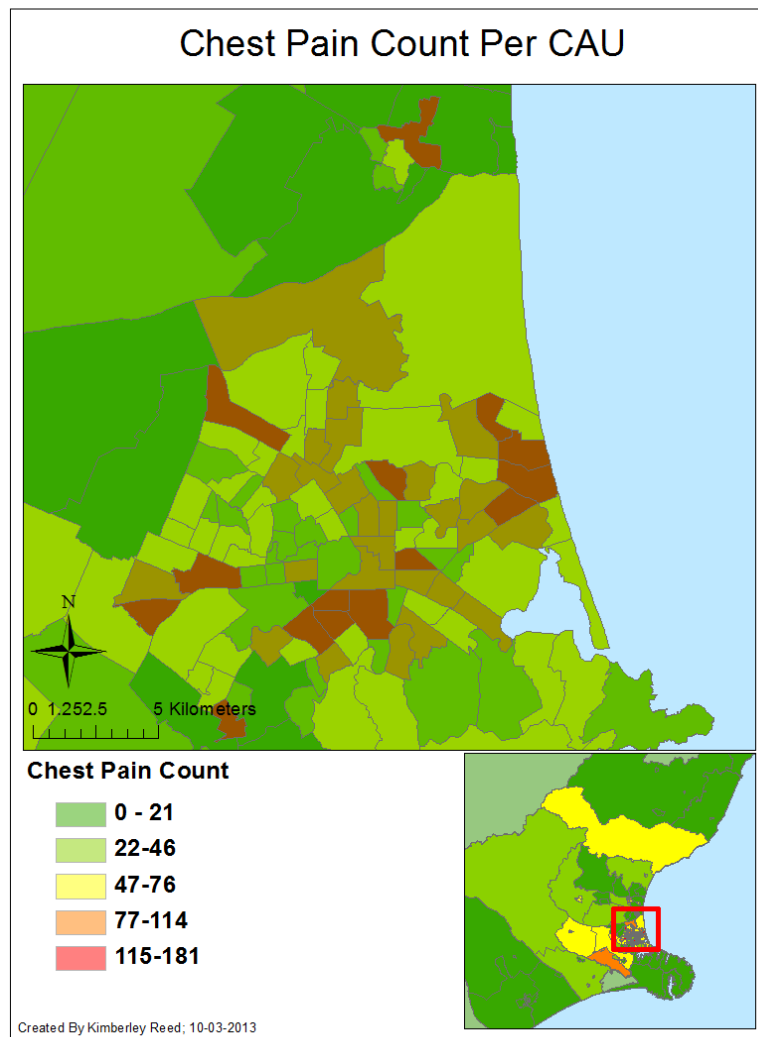


Figure 18: Chest Pain Counts

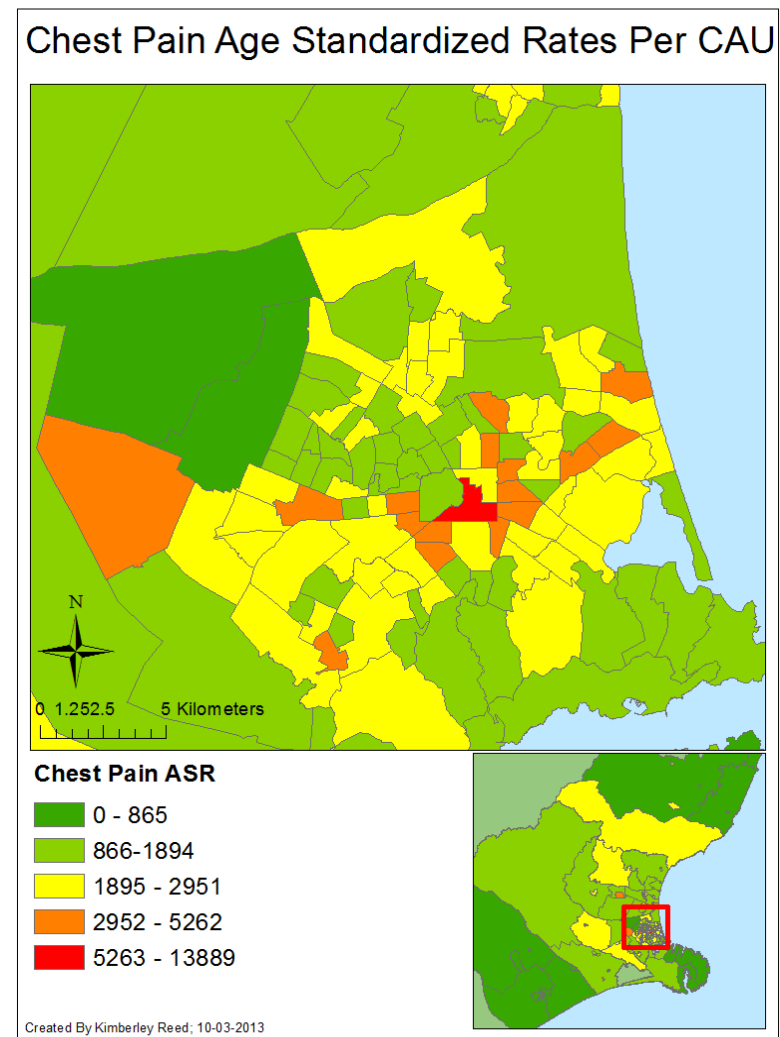


Figure 19: Chest Pain ASR

6.2 Spatio-temporal clusters of anxiety and chest pain

For both Chest Pain and Anxiety SaTScan cluster analysis software was used to identify any spatial, temporal or spatio-temporal clusters. The first model was purely spatial, the second purely temporal and thirdly a space-time model; each of the models account for deprivation and age.

6.2.1 Anxiety

Table 5: SatScan Results for Anxiety

Type of Analysis	Cluster Type	Time-Frame	Relative Risk	Log-Likelihood Ratio	p-value
Purely Spatial	Primary		1.96	28.6	<0.0001
	Secondary		0.069	20.8	<0.0001
	3		0.26	12.6	0.0019
	4		0.16	10.3	0.016
	5		0.42	4.5	0.835
Purely Temporal	Primary	1 st Aug 2010- 30 th Apr 2011	1.57	12.9	0.0001
Space-Time	Primary	1 st Aug 2010 – 30 th Apr 2011	2.17	29.4	<0.0001
	Secondary	1 st May 2010 – 31 st Oct 2010	0	15.3	0.0022

The SatScan Purely Spatial model found five clusters, 1 hot cluster and 4 cold clusters. The hot cluster (relative risk 1.96, $p < 0.0001$) is located across Christchurch City and the Port Hills as shown as the primary cluster in Table 5 and Figure 20. Three of the four cold clusters were significant, and were located in greater Christchurch CAUs. This indicates that there was a spatial cluster of anxiety across Christchurch, and cold spots in the wider CDHB region.

The purely temporal model found a significant hot cluster of Anxiety cases whilst controlling for age and deprivation between the 1st of August 2010 and the 30th of

April 2011 (Table 5). This indicates an increase in anxiety during the same periods as the two most damaging earthquakes occurred.

The Space-Time model shown in Table 5 and illustrated in Figure 21 indicates that there was a hotspot (relative risk 2.17, $p < 0.0001$) of Anxiety cases between the 1st of August 2010 until the 30th of April 2011, whilst controlling for age and deprivation across central Christchurch census area units, and excluded the most eastern CAUs. The Space-Time model also found a cold spot (relative risk 0, $p 0.0022$) of Anxiety cases between the 1st of May 2010 until the 31st of October 2010, whilst controlling for age and deprivation to the South West of Christchurch City, as illustrated in Figure 21 as the secondary cluster. These clusters show an increase in anxiety cases within Christchurch, and a cold spot of anxiety clusters in the wider CDHB region.

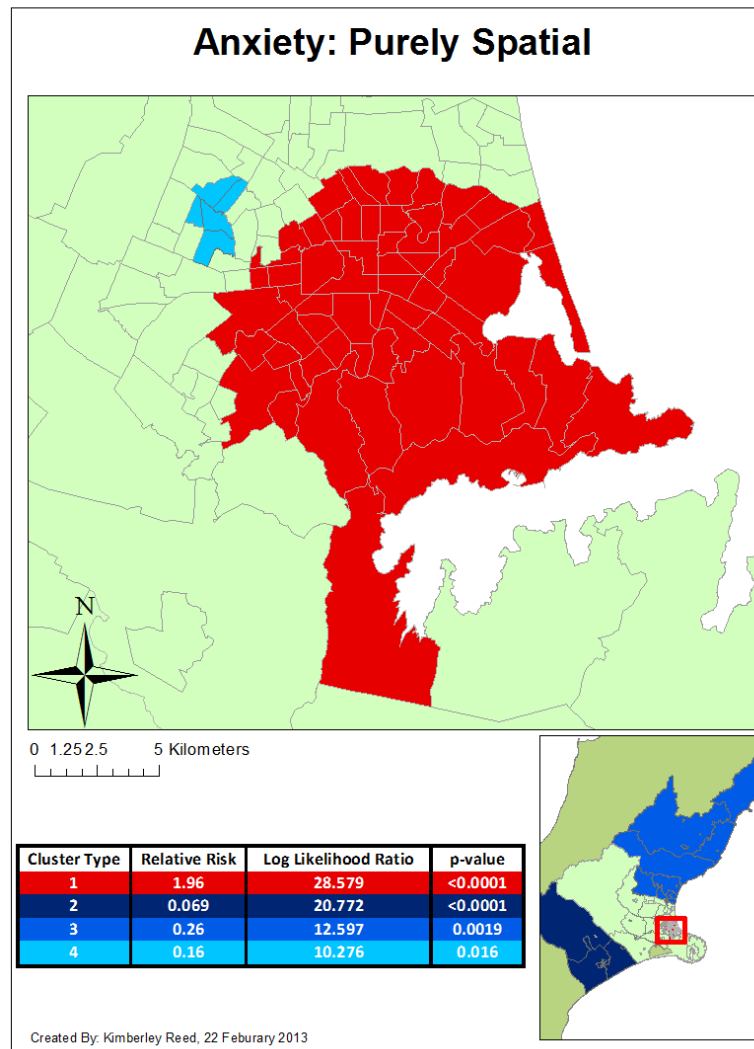


Figure 20: Purely Spatial Anxiety

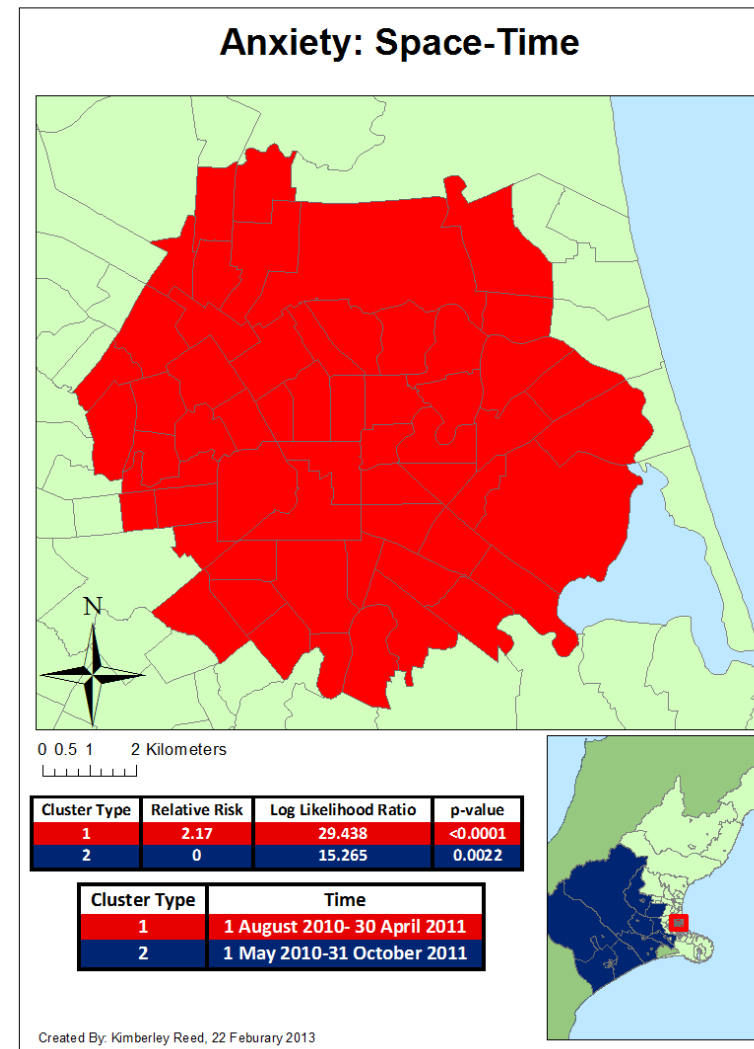


Figure 21: Space-Time Anxiety

6.2.2 Chest Pain

Three purely spatial clusters were found for chest pain whilst controlling for age and deprivation; the primary cluster being a cold spot (relative risk 0.073, $p < 0.0001$) and the second and third clusters were hot spots (relative risk 1.35, $p < 0.0001$; relative risk 1.11, $p 0.364$) however only the primary and secondary clusters were significant (Table 6 and Figure 22). The primary cluster (cold spot) is to the South West of the CDHB region, and the secondary cluster (hot spot) is located within Christchurch City CAUs however excluded the most eastern CAUs.

The purely temporal model for chest pain which controlled for age and deprivation found a significant hot spot (relative risk 1.27, $p 0.0001$) between the 1st of August 2010 and the 31st of October 2010 as shown in Table 6.

Two clusters were found in the space-time model for chest pain which controlled for age and deprivation as shown in Table 6 and Figure 23. The primary cluster was a significant cold spot (relative risk 0.062, $p < 0.0001$) between the 1st of February 2011 and the 31st of January 2012 and was located to the south west of the CDHB region. The secondary cluster was a significant hot spot (relative risk 1.41, $p < 0.0001$) between the 1st of May 2010 and the 30th of April 2011 and was located over Christchurch city however it excluded eastern CAUs, which indicates an increase in anxiety within Christchurch between the same time as the two most damaging earthquakes.

Table 6: SatScan Results for Chest Pain

Type of Analysis	Cluster Type	Time-Frame	Relative Risk	Log-Likelihood Ratio	p-value
Purely Spatial	Primary		0.07	426.0	<0.0001
	Secondary		1.35	110.5	<0.0001
	3		1.11	6.1	0.364
Purely Temporal	Primary	1 st Aug 2010-31 st Oct 2010	1.27	34.1	0.0001
Space-Time	Primary	1 st Feb 2011-31 st Jan 2012	0.06	220.6	<0.0001
	Secondary	1 st May 2010 – 30 th Apr 2011	1.41	111.3	<0.0001

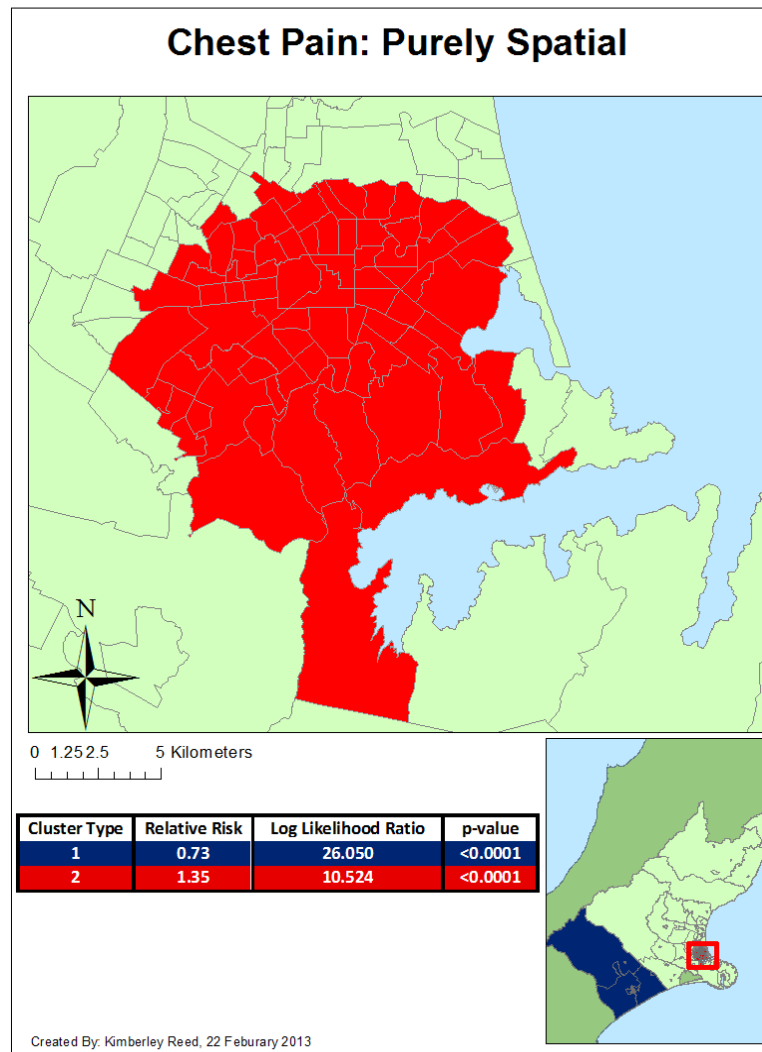


Figure 22: Purely Spatial Chest Pain

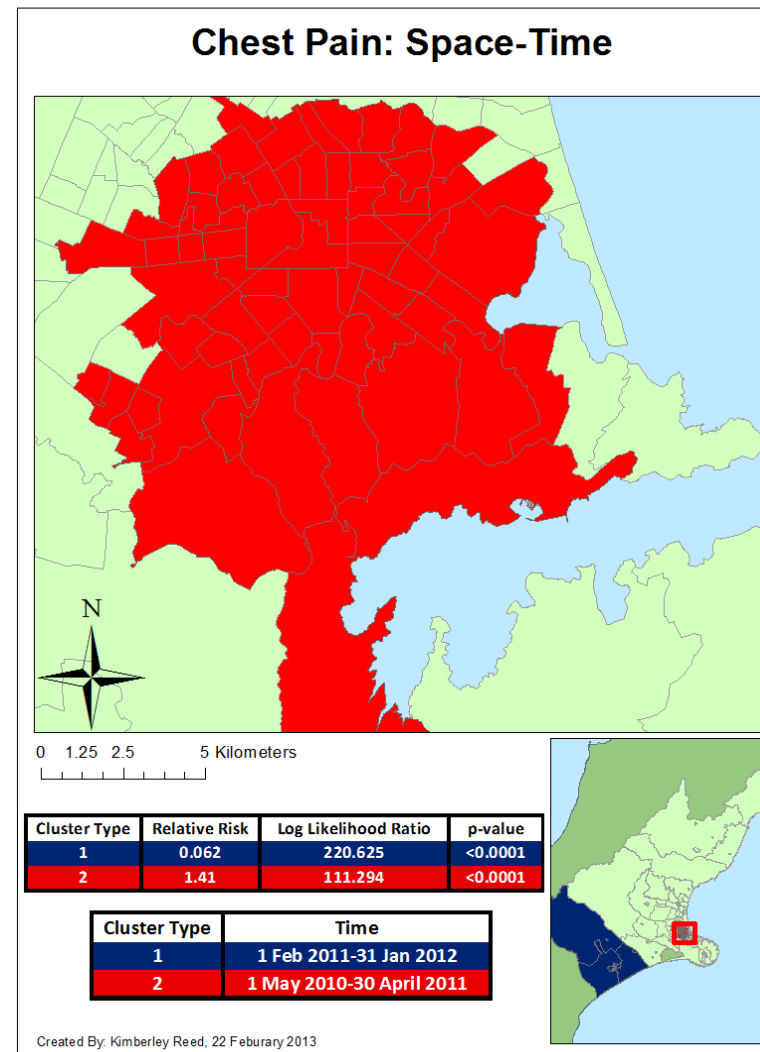


Figure 23: Space-Time Chest Pain

6.3 Associations between Anxiety, Chest Pain and Damage to Neighbourhood

To select the appropriate regression model, the distribution (Figure 24), mean and variance of anxiety counts were examined. The observed variance was over four times the value of the mean (mean=2.8, variance=12.3). Further investigation of the dependent variable revealed that almost one third (31.55%) of CAU level anxiety counts were 0 so a negative binomial regression was chosen. Examination of the likelihood ratio test for the over-dispersion parameter alpha found an alpha significantly different from zero suggesting that the dependent variable is over dispersed reinforcing the decision to use a negative binomial model (chi-square=72.84, $p < 0.000$).

6.3.1 Anxiety

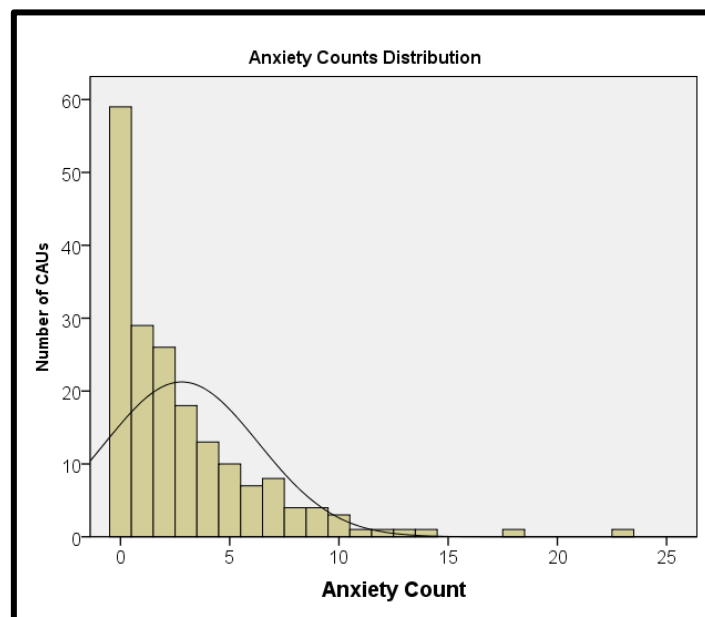


Figure 24: Anxiety Counts Distribution

Model 1 (Table 7) examined the association between anxiety (counts) and the independent variables: Percent low to moderate liquefaction; Percent moderate to severe liquefaction; Distance to liquefaction quintiles; and NZDepScore. Independent

variables were added in this order one at a time and a likelihood ratio test was used to examine if the addition of extra independent variables improved the model fit, which it did (chi-square = 29.69, p= <0.0001; chi-square=18.88, p=<0.01; chi-square=9.72, p>0.01). Thus the fully adjusted Model 1 included the CAU anxiety counts, independent variables: Percent Low to moderate liquefaction, percent moderate to severe liquefaction, categorical variables distance to liquefaction quintiles, and NZDepScore, using total CAU population counts as offsets.

Table 7: Liquefaction; Negative Binomial Results

Model	Variables	IRR	P	95% CI		LR chi ²	Prob > chi ²
1.1	Percent Low to Moderate Liquefaction	1.016	0.004	1.006	1.026		
1.2	Percent Low to Moderate Liquefaction	1.019	0.000	1.010	1.029		
	Percent Moderate to Severe Liquefaction	1.016	0.000	1.010	1.022		
						29.69	0.000
1.3	Percent Low to Moderate Liquefaction	1.016	0.008	1.004	1.027		
	Percent Moderate to Severe Liquefaction	1.013	0.001	1.006	1.021		
	DistLiq_2	1.122	0.574	0.752	1.674		
	DistLiq_3	1.096	0.723	0.659	1.823		
	DistLiq_4	0.747	0.313	0.423	1.317		
	DistLiq_5	0.391	0.004	0.205	0.747		
						18.88	0.001
1.4	Percent Low to Moderate Liquefaction	1.015	0.006	1.004	1.026		
	Percent Moderate to Severe Liquefaction	1.013	0.001	1.006	1.021		
	DistLiq_2	1.239	0.282	0.839	1.830		

DistLiq_3	1.260	0.365	0.765	2.074		
DistLiq_4	0.920	0.772	0.522	1.619		
DistLiq_5	0.473	0.022	0.248	0.899		
NZDepScore	1.003	0.002	1.001	1.005		
					9.72	0.002

Model 2 (Table 7) examined the association between anxiety (counts) and the independent variables percent red zone, distance to red zone quintiles, NZDepScore, percent orange zone, percent white zone. Independent variables were added in this order one at a time and a likelihood ratio test was used to examine if the addition of presence of these independent variables improved the model fit. The addition of distance to red zone and NZDepScore improved the model (Chi-Square=52.11, p=0.000) however the addition of percent orange zone and percent white zone did not improve the model (Chi-Square=0.86, p=0.652) and neither percent orange zone or percent white zone had significant Incident Rate Ratios (IRR=1.011, p=0.700; IRR=0.987, p=0.406). Thus, the fully adjusted model 2 included the CAU anxiety counts, independent variables percent red zone, categorical variable distance to red zone quintiles and NZDepScore using total CAU population counts as offsets.

Table 8 Land Zones; Negative Binomial Results

Model	Variables	IRR	P	95% CI Lower	95% CI Upper	LR chi ²	Prob > chi ²
2.1	Percent Red Zone	1.009	0.213	0.995	1.022		
2.2	Percent Red Zone	0.999	0.855	0.986	1.012		
	Dist_red_2	0.993	0.970	0.680	1.449		
	Dist_red_3	0.698	0.080	0.454	1.045		
	Dist_red_4	0.473	0.002	0.298	0.752		
	Dist_red_5	0.277	0.000	0.155	0.494		
	nzdepscore	1.003	0.003	0.001	1.005		
						52.11	0.000
2.3	Red	0.999	0.844	0.986	1.012		
	Orange	1.011	0.700	1.956	1.069		
	White	0.987	0.406	0.957	1.018		
	Dist_red_2	0.991	0.963	0.679	1.448		
	Dist_red_3	0.705	0.101	0.464	1.071		
	Dist_red_4	0.478	0.002	0.301	0.758		
	Dist_red_5	0.275	0.000	0.154	0.490		
	NZDepScore	1.003	0.004	1.001	1.005		
							0.86

Model 3 (Table 8) examined a combination of liquefaction and land zone variables. The dependent variable was anxiety (counts), the independent variables were percentage of land parcels zoned red per CAU, percentage of land parcels with low to moderate liquefaction, percentage of land parcels with moderate to severe liquefaction, and NZdepScore. In model 3.1 which did not include NZdepScore none of the variables were significant, however with the addition of NZdepScore the model became stronger (chi²=50.32, p<0.001) and all independent variables with the exception of percentage of land parcels zoned red became significant.

The fully adjusted model 3.2, is shown in Table 9. Anxiety counts by CAU were significantly associated with percentage of low to moderate liquefaction and moderate to severe liquefaction with IRRs of 1.016 and 1.014 respectively. This

equates to a 1.6% and 1.4% increase in anxiety counts for every 1% increase in the respective liquefaction within the CAU. NZdep Score was also significantly associated with area-level anxiety counts.

Table 9 Liquefaction and Land Zones; Negative Binomial Results

Model	Variables	IRR	P	95% CI Lower	95% CI Upper	LR chi ²	Prob > chi ²
3.1	Percent Red Zone	0.827	0.025	0.700	0.977		
	Percent Low to moderate Liquefaction	1.022	0.311	0.980	1.067		
	Percent Moderate to Severe Liquefaction	1.004	0.590	0.991	1.017		
3.2	Percent Red Zone	.9970	0.640	.9847	1.0095		
	Percent Low to Moderate Liquefaction	1.0160	0.000	1.0072	1.0248		
	Percent Moderate to Severe Liquefaction	1.0141	0.000	1.0080	1.0202		
	NZdepScore	1.0031	0.001	1.0013	1.0048		
						50.32	0.0000

6.3.2 Chest Pain

In order to determine what type of regression analysis to perform, the distributions of chest pain age standardized rate were examined, using the histogram tool in SPSS. The chest pain ASR are approximately normally distributed however there is an outlier (Figure 25). This outlier has been removed from future analysis, and the distribution of chest pain ASR without the outlier is shown in Figure 26. Chest pain ASR are approximately normally distributed; therefore linear regression is the best regression model to explore the relationships with the indicators of earthquake damage.

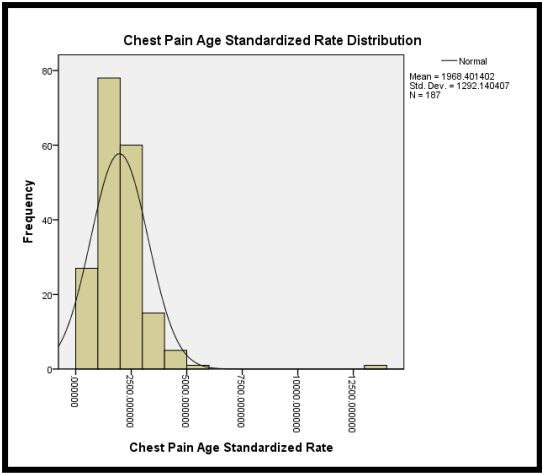


Figure 25 - Chest Pain Age Standardized Rate Distribution

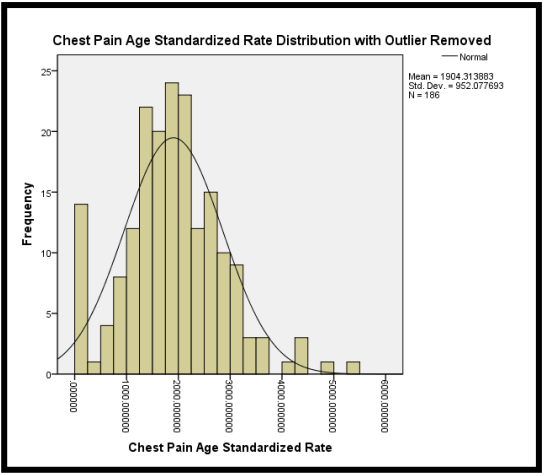


Figure 26- Chest Pain Age Standardized Rate Distribution with Outlier Removed

Before running any linear regression models, scatterplots were created (Figure 27) and Pearson Correlation tests (Table 10) were run between the independent and dependent variables to check whether there was a linear relationship between the two variables. As a result of visually interpreting the scatter graphs shown in Figure 28 and the correlations shown in Table 10, percentage of land parcels zoned red was excluded from the linear regression analysis.

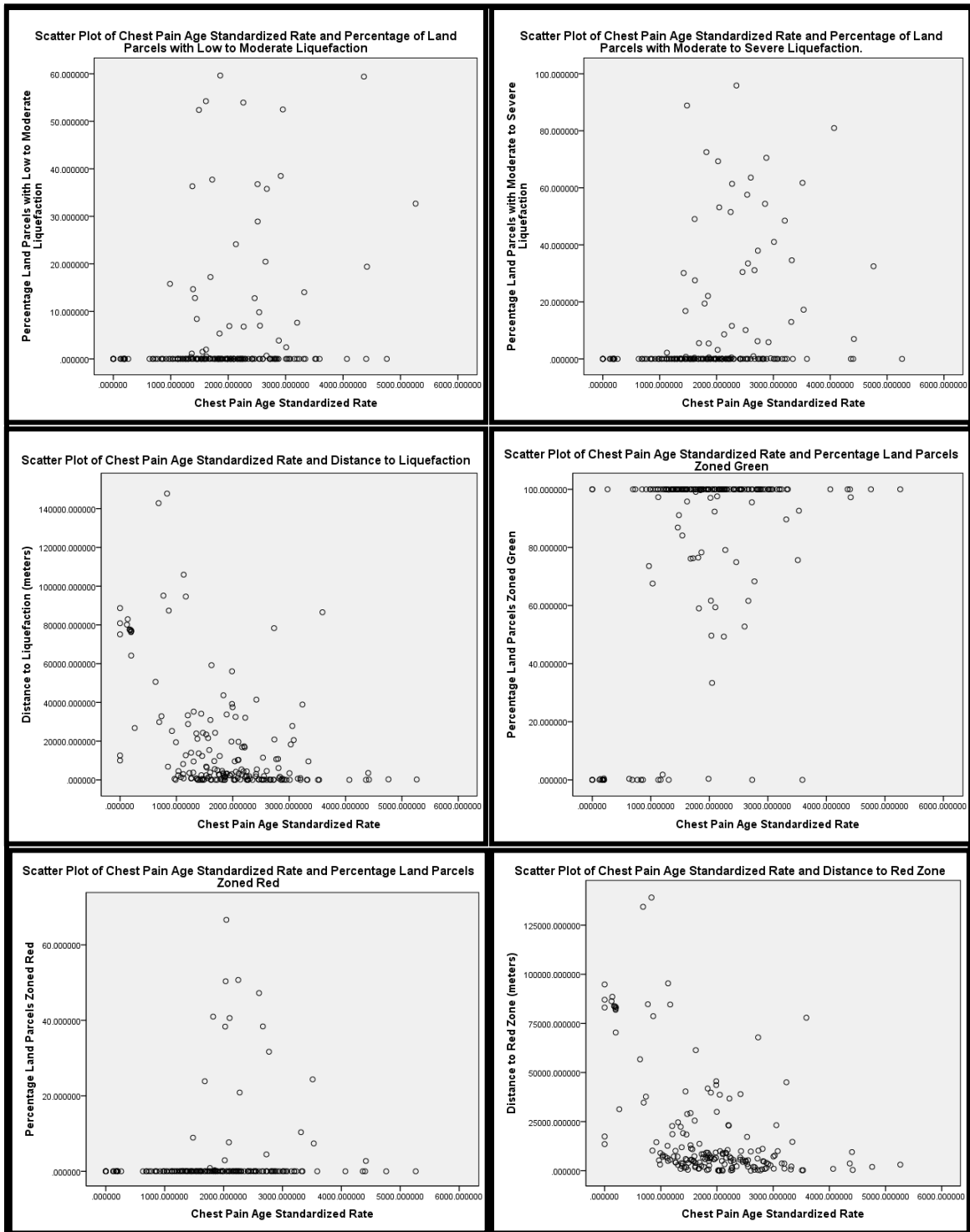


Figure 27 Scatter Plots of Chest Pain Age Standardized Rates and Independent Variables

Table 10: Correlations of Chest Pain and Independent Variables

		Chest Pain Age Standardized Rate	Percentage Land Parcels with Low to Moderate Liquefaction	Percentage Land Parcels with Moderate to Severe Liquefaction	Distance to Liquefaction (meters)	Distance to Red Zone (meters)	Percentage Land Parcels Zoned Green	Percentage Land Parcels Zoned Red
Chest Pain Age Standardized Rate	Pearson Correlation	1	.216**	.270**	-.470**	-.498**	.430**	.115
	Sig. (2-tailed)		.003	.000	.000	.000	.000	.116
	N	186	186	186	186	186	186	186
Percentage Land Parcels with Low to Moderate Liquefaction	Pearson Correlation	.216**	1	-.048	-.216**	-.201**	.157**	-.092
	Sig. (2-tailed)	.003		.514	.003	.006	.032	.210
	N	186	186	186	186	186	186	186
Percentage Land Parcels with Moderate to Severe Liquefaction	Pearson Correlation	.270**	-.048	1	-.247**	-.250**	.032	.440**
	Sig. (2-tailed)	.000	.514		.001	.001	.669	.000
	N	186	186	186	186	186	186	186
Distance to Liquefaction (meters)	Pearson Correlation	-.470**	-.216**	-.247**	1	.981**	-.800**	-.140
	Sig. (2-tailed)	.000	.003	.001		.000	.000	.057
	N	186	186	186	186	186	186	186
Distance to Red Zone (meters)	Pearson Correlation	-.498**	-.201**	-.250**	.981**	1	-.790**	-.180
	Sig. (2-tailed)	.000	.006	.001	.000		.000	.014
	N	186	186	186	186	186	186	186
Percentage Land Parcels Zoned Green	Pearson Correlation	.430**	.157**	.032	-.800**	-.790**	1	-.191**
	Sig. (2-tailed)	.000	.032	.669	.000	.000		.009
	N	186	186	186	186	186	186	186
Percentage Land Parcels Zoned Red	Pearson Correlation	.115	-.092	.440**	-.140	-.180	-.191**	1
	Sig. (2-tailed)	.116	.210	.000	.057	.014	.009	
	N	186	186	186	186	186	186	186

** . Correlation is significant at the 0.01 level (2-tailed).

* . Correlation is significant at the 0.05 level (2-tailed).

Table 11 shows the first six Linear Regression Models run. Individually each variable is significant, with Distance to Liquefaction, Distance to Red Zone and Percentage of Land Zoned Green having strong R values. NZDepScore as expected was also significantly related to Chest Pain Age Standardised Rates, therefore the next linear regression models controlled for NZDep Score.

As shown in Table 12, controlling for NZDepScore strengthened the R and R² values whilst keeping all of the variables significant. This indicates that deprivation had an influence on each of the variables. Of these, the best predictors of chest pain whilst controlling for deprivation are distance to red zone and distance to liquefaction.

Table 13 shows the strongest linear regression model. Although percentage of land parcels with low to moderate liquefaction is not significant it still strengthens the R and R² values indicating that including percentage of land parcels with low to moderate liquefaction improves the model. This model has a high F Ratio, and strong R and R² values therefore the best Linear Regression model for predicting Chest Pain ASR within a CAU controlled for NZDepScore and includes the following variables: Percentage Land Parcels with Low to Moderate Liquefaction; Percentage Land Parcels with Moderate to Severe Liquefaction; Distance to Liquefaction (meters); Distance to Red Zone (meters); and Percentage of Land Parcels Zoned Green. This model is able to account for 37.9% of chest pain age standardized rates. Table 14 provides examples of this model applied, and shows that the CAUs with an average amount of damage had the lowest ASR per 100,000, and the CAUs with the greatest damage also had the highest ASR per 100,000.

Table 11: Linear Regression for Results for Chest Pain and Independent Variables

	Variable	Mean	Standard Deviation	R	R ²	F	F Significant	t	T Sig.	Regression Equation
Model 1	Percentage Land Parcels with Low to Moderate Liquefaction	4.2720	12.0568	0.216	0.047	9.037	0.003	3.006	0.003	=1831.325+(17.085*Percentage Land with Low to Moderate Liquefaction)
Model 2	Percentage Land Parcels with Moderate to Severe Liquefaction	7.7178	19.1629	0.270	0.073	14.498	0.000	3.808	0.000	=1800.687+(13.427*Percentage Land Parcels with Moderate to Severe Liquefaction)
Model 3	Distance to Liquefaction (Meters)	17327.4438	28404.3114	0.470	0.221	52.215	0.000	-7.226	0.000	=2177.380+(-.016*Distance to Liquefaction)
Model 4	Distance to Red Zone (Meters)	18286.9496	27508.5468	0.498	0.248	60.801	0.000	-7.797	0.000	=2219.738+(-0.017*Distance to Red Zone)
Model 5	Percentage Land Zoned Green	83.2912	33.9188	0.430	0.185	41.833	0.000	6.468	0.000	=898.086+(12.081*Percentage Land Parcels Zoned Green)
Model 6	NZDep Score	965.2151	69.4829	0.332	0.110	22.777	0.000	4.773	0.000	=-2485.232+(4.548*NZDep Score)

Table 12: Linear Regression Results for Chest Pain, Independent Variables and NZDep Score

	Variable	R	R ²	Durbin Watson	F	F Significant	t	T Sig.	Regression Equation
Model 7	Percentage Land Parcels with Low to Moderate Liquefaction Score	0.371	0.137	0.282	14.559	0.000	2.398	0.017	=-2183.304+(4.177*NZdep Score)+(13.179*Percentage Land Parcels with Low to Moderate Liquefaction)
Model 8	Percentage Land Parcels with Moderate to Severe Liquefaction	0.384	0.147	0.307	15.814	0.000	2.826	0.005	=-1897.780+(3.860*NZDepScore)+(9.902*Percentage Land Parcels with Moderate to Severe Liquefaction)
Model 9	Distance to Liquefaction (meters)	0.548	0.300	0.509	39.184	0.000	-7.041	0.000	=-1577.320+(0.387*NZDepScore)+(-0.015*Distance to Liquefaction)
Model 10	Distance to Red Zone	0.572	0.327	0.537	44.479	0.000	-7.687	0.000	=-1531.390+(3.867*NZDepScore)+(-0.016*Distance to Red Zone)
Model 11	Percentage Land Parcels Zoned Green	0.537	0.289	0.503	37.174	0.000	6.782	0.000	=-3343.730+(4.413*NZDepScore)+(11.870*Percentage Land Parcels Zoned Green)

Table 13: Linear Regression Results for a Combination of Independent Variables and NZDepScore

	Variable	R	R ²	Durbin-Watson	F	F Sig.	t	T Sig.	Regression Formula
Model 12	Combined	0.615	0.379	0.682	18.191	0.000			= -1985.064 + (3.469 * NZDepScore) + (9.164 * Percentage Land Parcels with Low to Moderate Liquefaction) + (7.647 * Percentage Land Parcels with Moderate to Severe Liquefaction) + (0.026 * Distance to Liquefaction) + (-0.033 * Distance to Red Zone) + (7.251 * Percentage Land Parcels Zoned Green)
	NZDepScore						4.086	0.000	
	Percentage Land Parcels with Low to Moderate Liquefaction						1.878	0.062	
	Percentage Land Parcels with Moderate to Severe Liquefaction						2.340	0.020	
	Distance to Liquefaction (meters)						2.498	0.013	
	Distance to Red Zone (meters)						-3.198	0.002	
	Percentage Land Parcels Zoned Green						2.511	0.013	

Table 14: Linear Regression Model Applied Scenarios

	NZDep Score	Percentage of land parcels with low to moderate liquefaction	Percentage land parcels with moderate to severe liquefaction	Distance to liquefaction (m)	Distance to red zone (m)	Percentage land parcels zoned green	Expected ASR/ 100,000
Least Damage CAU	966	4.4334	7.92458	1723.6	18186.6	85.2031	1529.68
Average Damage CAU	1155	0	0	147788.3	139087.8	100	1999.329
Greatest Damage CAU	859	4.11	95.89	0	0	0	769013.2

6.4 Differences in anxiety counts and chest pain counts after each major earthquake and aftershock which resulted in severe physical damage.

6.4.1 Anxiety

A visual interpretation of Figure 28 which shows when an earthquake occurred and monthly anxiety counts, identified a possible lag effect between when the earthquake occurred and when people presented to Christchurch Public Hospitals ED for anxiety. This relationship was further examined by calculating correlations between anxiety counts the month of a large earthquake, and also the following month. The correlation results are presented in Table 15 and show there is no significant relationship in anxiety counts the month of an earthquake, however there is a significant positive linear relationship one month after a large earthquake (Pearsons Correlation = 0.396, $p < 0.028$).

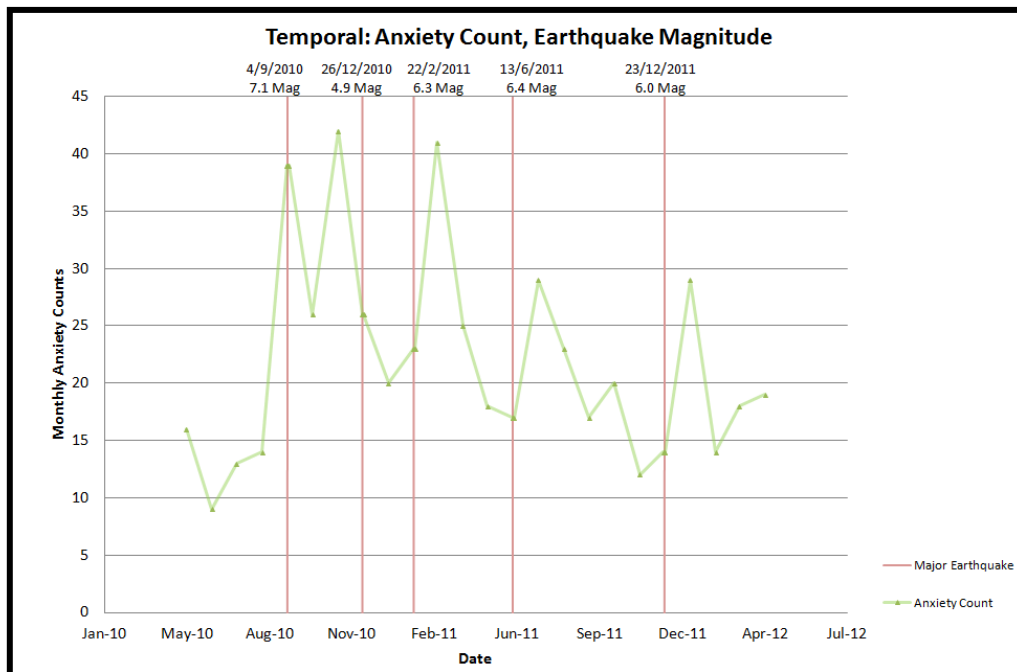


Figure 28: Temporal Relationships between Anxiety and Date of Earthquakes

Table 15: Correlation Results between Anxiety and Months Following an Earthquake

	Pearson Correlation	Sig.	N
Same month as Earthquake	0.090	0.338	24
1 month after Earthquake	0.396	0.028	24

The temporal relationship between when an earthquake occurred and anxiety counts was also examined using a linear regression model with dummy variables. The results of this model are presented in Table 15 and confirm that the anxiety counts the month of an earthquake are not significant with poor F-ratio and t values. The month following an earthquake there is a strong significant relationship, with the model accounting for 19.2% of the variation in anxiety counts, and predicts that in the month following an earthquake, anxiety counts will be 29 (the mean anxiety counts per month were 21.8, SD= 9.01).

Table 16: Linear Regression Results Showing Temporal Relationship between Months Following an Earthquake and Anxiety Counts

	R	R²	F-ratio	Sig.	t	Sig.	Regression Formula
Same month as Earthquake	0.090	0.008	0.178	0.677	0.422	0.677	The month an earthquake occurs, anxiety counts within the CDHB region = 23.8
1 month after Earthquake	0.439	0.192	2.500	0.106	2.189	0.040	Within the first two months of an earthquake, anxiety counts within the CDHB Region = 29

6.4.2 Chest Pain

The temporal relationship between weekly chest pain counts and when an earthquake occurred has been explored over the eight weeks following an

earthquake (Figure 29). It is possible to see a visual relationship between when an earthquake occurred and chest pain counts. The correlation results (Table 17) indicate that within the first eight weeks following an earthquake there were significant positive linear relationships between the weeks following an earthquake and chest pain counts.

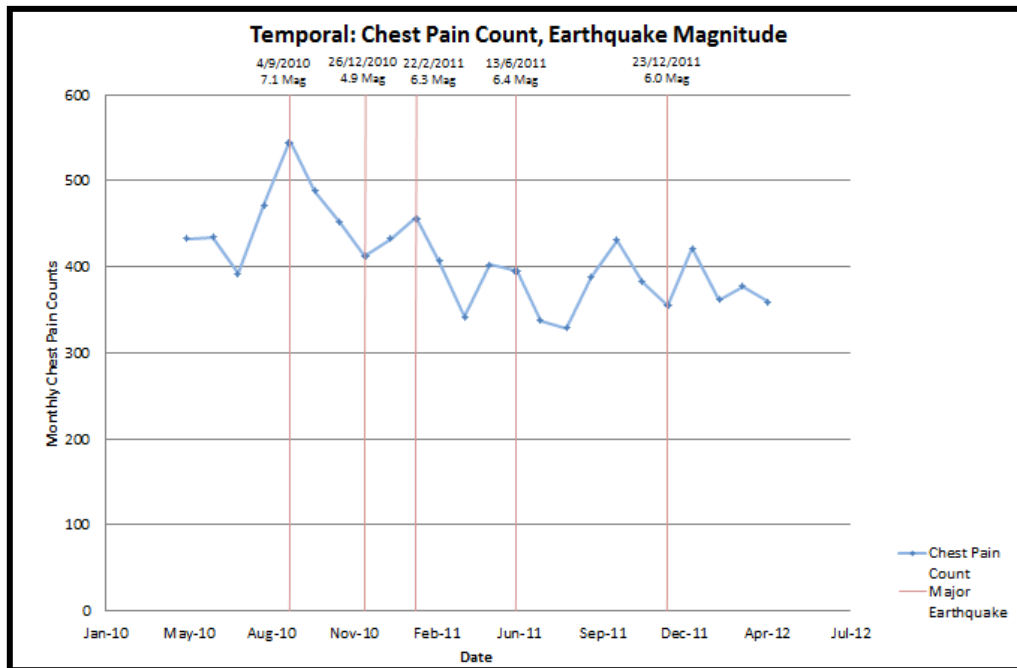


Figure 29: Temporal Relationships between Chest Pain and Date of Earthquakes

Table 17: Correlation Results between Chest Pain and Weeks Following an Earthquake

	Pearson Correlation	Sig.	N
Week	0.219	0.013	104
Week +1	0.346	0.000	104
Week +2	0.330	0.000	104
Week +3	0.297	0.001	104
Week +4	0.220	0.012	104
Week +5	0.202	0.020	104
Week +6	0.212	0.015	104
Week +7	0.193	0.025	104

The linear regression results (Table 18) show that the relationships between time (weekly) accumulating up to eight weeks after an earthquake, and chest pain counts

have significant relationships, this is further reinforced by strong significant F-ratio and t values. Chest Pain counts peak one week following the earthquake, with an expected count of 110.6, compared to the mean actual chest pain count per week 96.5. It can also be seen that as the number of weeks increase after an earthquake the expected chest pain counts will also continue to decrease (Figure 30).

Table 18: Linear Regression Results Showing Temporal Relationship between Weeks Following an Earthquake and Chest Pain Counts

	R	R ²	F-ratio	Sig.	t	Sig.	Expected Chest Pain Counts Calculated from Regression Formula
Week	0.219	0.048	5.115	0.026	2.262	0.026	109.2
Week +1	0.346	0.120	13.891	0.000	3.727	0.000	110.6
Week +2	0.330	0.109	12.424	0.001	3.525	0.001	106.534
Week +3	0.297	0.088	9.900	0.002	3.146	0.002	103.5
Week +4	0.220	0.049	5.210	0.025	2.283	0.025	100.08
Week +5	0.202	0.041	4.325	0.040	2.080	0.040	98.9
Week +6	0.212	0.045	4.801	0.031	2.191	0.031	98.6
Week +7	0.193	0.037	3.928	0.050	1.982	0.050	97.75

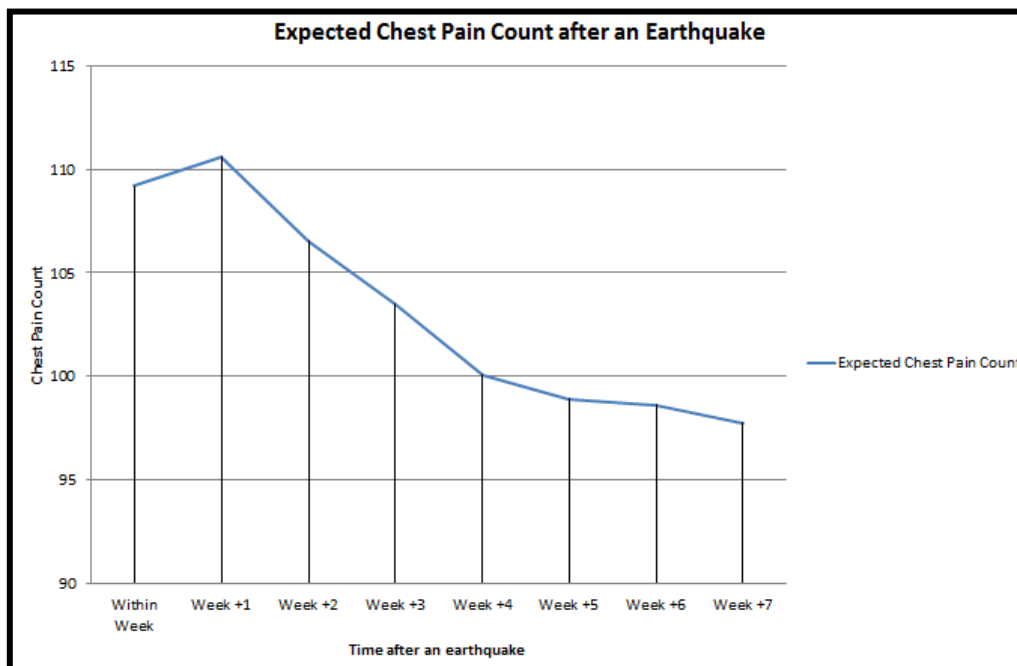


Figure 30: Line Graph showing Expected Chest Pain Counts Following an Earthquake

6.5 Results Summary

This chapter presented the results of this research with a focus on the three research objectives.

The spatio-temporal analysis which scanned for spatial, temporal and spatio-temporal clusters of anxiety and chest pain found a hot cluster in anxiety counts across Christchurch city excluding the most Eastern CAUs between August 1, 2010 and April 30, 2011. The analysis also found a hot cluster in chest pain counts across Christchurch city excluding the most eastern CAUs between May 1, 2010 and April 30 2011.

The negative binomial regression analysis of anxiety and damage to neighbourhood, found anxiety counts by CAU were significantly associated with the percentage of land parcels with low to moderate and moderate to severe liquefaction. For every 1% increase in low to moderate and moderate to severe liquefaction, the model estimates a 1.6% and 1.4% increase in anxiety counts respectively. This analysis also found liquefaction to be a stronger predictor of anxiety than chest pain.

The linear regression analysis of chest pain and measures of earthquake damage found that the combination of percentage of land parcels with low to moderate liquefaction, moderate to severe liquefaction, distance to red zone, distance to liquefaction and percentage of land parcels zone green, and NZdep Score can account for 37.9% of chest pain age standardized rates.

The temporal analysis of anxiety counts which used dummy variables within a linear regression model found that one month after an earthquake anxiety counts increased by 33% above the mean. The temporal analysis of chest pain counts

found that chest pain peaked 2 weeks, where counts were 15% above the mean; over the following 5 weeks these counts gradually decreased.

7.0 Discussion

The aim of this research was to examine the spatial and spatio-temporal patterns of anxiety and chest pain resulting from the Canterbury earthquakes. Three research questions were identified:

1. Are there spatio-temporal clusters of anxiety and chest pain?
2. What is the association with anxiety, chest pain and damage to neighbourhood?
3. Is there a statistically significant difference in counts of anxiety and chest pain after each significant earthquake and aftershock which resulted in severe physical damage?

In this chapter, the results of each of the three research questions are discussed along with any theoretical and policy implications. The limitations of the research are identified and recommendations for future research are provided.

7.1 Discussion of key findings

7.1.1 Spatio-temporal clusters of anxiety and chest pain

Anxiety

The key findings of the analysis using SaTScan which scanned for hot and cold clusters of anxiety and chest pain was the identification of a hot cluster in anxiety counts across Christchurch city excluding the most eastern CAUs between August 1, 2010 and April 30, 2011. The identification of a hot spot during this time period matches what could have been expected, given that this is the time period when the two most damaging earthquakes occurred, September 2010 and February 2011. The

hot spot is located across Christchurch city, however excluded the most eastern CAUs. The most eastern CAUs experienced some of the greatest physical damage with severe liquefaction and many properties subsequently red zoned. A similar pattern to where the CAUs with the most damage suffered less anxiety than those with moderate damage is supported by the existing literature; for example, Li et al., 2010 reported after the 2008 Sichuan Province, China earthquake, residents in the most damaged regions felt less concern about safety and health than those in non-damaged regions. Li et al., 2010 hypothesised that this may be due to the 'Psychological Typhoon Eye' (Liang et al., 2008) where residents furthest from the most damaged regions had greater anxiety. Another potential reason for this is the change in population. The PHO enrolment data was used as a proxy measure of population, however this research did not track the movements of people which limits the validity of the results.

Chest Pain

The space-time model for chest pain identified a hot spot in a similar location to anxiety which also excluded the most eastern suburbs however was between May 1, 2010 and April 30 2011. This hot spot cluster of chest pain began before the first earthquake in September 2010, however this may be due to the winter season which has been linked to increased rates of chest pain related health outcomes (Bhattacharyya & Steptoe, 2007). As with anxiety, the hot spot for chest pain excluded the most eastern suburbs, this may also be due to the 'Psychological Typhoon Eye' (Liang et al., 2008).

7.1.2 Associations between anxiety, chest pain and damage to neighbourhood

Anxiety

The associations between anxiety and damage to neighbourhoods were measured using negative binomial regression analysis. Various models were developed to examine the relationships between anxiety; the independent variables: percentage of CAU land parcels with low to moderate or moderate to severe liquefaction, percentage of CAU land parcels zoned red, distance to nearest red zone quintiles and distance to nearest liquefaction quintiles; and the control variable NZDep. The strongest model included the independent variables land parcels with low to moderate and moderate to severe liquefaction and controlled for NZDep. For every 1% increase in low to moderate and moderate to severe liquefaction, the model estimates a 1.6% and 1.4% increase in anxiety respectively. This finding that with greater damage to neighbourhood anxiety can be expected to increase is well documented within the existing literature (Ching-Hong et al., 2004; Eksi, 2009; Hsu et al., 2002; P. Kun et al., 2009; Matsuoka et al., 2000; Ogawa et al., 2000; B. Wang et al., 2011; Xu & He, 2012).

The negative binomial analysis of anxiety also highlighted that liquefaction is a stronger predictor of anxiety than land being red zone. This may be due to the 'Psychological typhoon eye' (Liang et al., 2008), as the areas with the most severe physical damage have been zoned red. This may also be due to this study not tracking the population movement and aggregating data to a CAU, perhaps the findings may have been different if a finer area scale was used.

Chest Pain

Linear regression analysis was performed to examine the relationships between chest pain and the independent measures of damage caused by the earthquake. The percentage of land parcels zoned red was not found to have a significant linear

relationship with chest pain so was excluded from further analysis. One potential reason for the lack of relationship between red zone and chest pain may be because those who live in the red zone know they will get to leave the area when the government buys their property. Individually distance to liquefaction, distance to red zone and percentage of land parcels zoned green had the strongest significant correlations with chest pain. This relationship between distance to red zone and distance to liquefaction was as expected, and highlights that those living within close proximity to liquefaction, and red zone experienced an increase in chest pain. There could be many reasons for this relationship; including the increased stress of living within Christchurch after the earthquakes and also that those living within Christchurch have greater accessibility to Christchurch Public Hospital than those in the wider CDHB region. It is also interesting to note the strong positive linear relationship between chest pain and percentage of land parcels zoned green; this finding requires greater research to be able to understand.

The strongest linear regression model which controlled for NZDep found that the percentage of land parcels with low to moderate liquefaction, moderate to severe liquefaction, distance to red zone, distance to liquefaction and percentage of land parcels can account for 37.9% of chest pain age standardized rates. When the model was applied to various scenarios, it was evident that age standardized rates were lower for CAUs that had average exposure to earthquake damage compared to those that had the least exposure within the CDHB region. Again this finding supports that of Li et al., 2010 where those with the least exposure had higher post-earthquake concern than those with moderate damage. In the model scenarios, those with the greatest exposure to physical damage had the highest ASR of chest

pain, this finding is widely supported within the academic literature (Armenian et al., 1997; Armenian et al., 1998; Ching-Hong et al., 2004; Ogawa et al., 2000)

7.1.3 Relationships between when an earthquake occurred and when people reported anxiety or chest pain.

Anxiety

The linear regression model which used dummy variables to measure the variation in anxiety over time found no significant increase in anxiety cases during the month of an earthquake, however in the month following the model showed that anxiety increased by approximately 33%. There could be numerous reasons for this delay in people presenting to CPH ED with anxiety, including people not wanting to overload the health system during a time of state of emergency given that immediately after an earthquake there is a large increase in physical injuries (Akbari et al., 2004; Armenian et al., 1998; Chan, 2003; Ching-Hong et al., 2004; Leor, Kloner, et al., 1996; Liao et al., 2005; Malilay, 1995; Matsuoka et al., 2000; Peek-Asa et al., 1998; Salinas et al., 1998). Another potential reason could be due to the delayed onset of anxiety; directly after the major earthquakes other health facilities may have been the first port of call for people suffering from anxiety.

Chest Pain

As with anxiety, dummy variables were used within linear regression to examine the temporal relationship between when an earthquake occurred and when people presented with chest pain. Given the large number of chest pain cases it was possible to do this analysis at a weekly interval.

Chest pain was found to have peaked two weeks after an earthquake with a 15% increase from the mean number of chest pain cases. Over the following five weeks chest pain counts gradually decreased. Similar findings have been identified within the existing literature, for example, after the 1999 Taiwan earthquake, myocardial infarction increased for 6 weeks after the earthquake (Ching-Hong et al., 2004); and after the 1995 Kobe, Japan earthquake myocardial infarction increased for 8 weeks following the earthquake (Ogawa et al., 2000).

7.2 Theoretical Implications

This thesis has taken a unique approach to examining the spatial and spatio-temporal variations of anxiety after an earthquake. This study offers unique results as it is the first study of its kind to use a GIS approach in examining these variables after the Canterbury earthquakes at a CAU level.

As discussed earlier in this chapter, the findings of this thesis are well supported within the existing literature. There is some variation within the existing literature around the effect of high exposure within ones neighbourhood on anxiety and chest pain. Some of the existing literature has found a positive relationship between exposure to earthquake damage as having a positive relationship with anxiety and chest pain (Ching-Hong et al., 2004; Eksi, 2009; Hsu et al., 2002; P. Kun et al., 2009; Matsuoka et al., 2000; Ogawa et al., 2000; B. Wang et al., 2011; Xu & He, 2012) however the findings of this thesis supports Li et al., 2010 where the most damaged neighbourhoods had less post-earthquake concern than those with minor damage.

The existing literature has used various methods to analyse destruction to neighbourhood for example Matsuoka et al. (2000) created destruction ratios which

represent damage to neighbourhood variables. Another approach within the existing literature was to measure damage to neighbourhood based of the percentage of damaged houses (Ogawa et al., 2000). Given the uniqueness of the Canterbury earthquakes previously un-used variables relating to the red zone and liquefaction were used as a proxy of damage to neighbourhood, which helps to make the findings of this thesis unique.

The findings of the temporal analysis of chest pain after an earthquake support the bulk of the existing literature, where chest pain increases in the weeks following an earthquake (Ching-Hong et al., 2004; Ogawa et al., 2000). However the finding that chest pain did not increase until two weeks after an earthquake differs from the bulk of the existing literature which has identified that chest pain peaks within the first week of an earthquake (Gold et al., 2007; Leor, Poole, et al., 1996).

7.3 Policy Implications

The findings of this thesis can be used to guide public health policy decisions when planning the allocation of resources following a large earthquake or natural disaster. The results of this study show that mental health and wellbeing resources need to be made available to not only to the CAUs that suffered the most physical damage, but also to those who suffered low to moderate physical damage. These resources need to be provided in the weeks and months following an earthquake, as the findings of this research indicate there can be a delayed response after a major earthquake.

This research also highlights the need to consider socio-economic factors when allocating resources. This research continuously highlights the increase in anxiety and chest pain within the most deprived neighbourhoods.

7.4 Limitations of the Analysis

There are some limitations of this research which need to be taken into consideration when interpreting the results. As highlighted within Chapter 3 there are numerous variables which can influence anxiety and chest pain after an earthquake. Given the availability of population data and also the ethical limitations of the health data this research has only controlled for deprivation and age within some of its analysis.

Another limitation of this data was the availability of health data. This research has only focussed on anxiety and chest pain of those who attended Christchurch Public Hospital ED between May 2010 and April 2012. Given that after the February 2011 earthquake, Cantabrians were encouraged to see alternative medical facilities and only present to Christchurch Public Hospital ED if it was urgent; a stronger analysis could have included data from these alternative medical facilities. Due to ethical limitations and the availability of data it was not possible to collect data from prior to May 2010. Perhaps a longer control period would have made it possible to identify any pre-existing temporal patterns of anxiety and chest pain. If more data had been available, then it may have been possible to have used a finer area scale such as meshblocks as well as enabled temporal analysis to be completed at weekly intervals.

Ethical restrictions and availability of data also limited what area scale could be used for this analysis. CAUs were chosen to represent all households within the CAU boundary, however perhaps a finer area scale would have produced different results. This concept of variation in results due to the area scale is also known as the modifiable area unit problem, which is a well-recognised within health research which has used aggregated area levels in GIS.

There has been large movement of population as a result of the earthquakes, including households having to move as their properties have been zoned red and the government has purchased them. Along with households moving permanently, some households have had to relocate temporarily whilst they have earthquake damage repaired. Although we used quarterly PHO enrolment data which allowed the analysis to account for population change; the analysis did not take into consideration where people had moved. For example, the results show that the most damaged neighbourhoods had less anxiety than the moderately damaged neighbourhoods. If this study had population movement data then the analysis could have controlled for people who have moved from the most damaged neighbourhoods to less damaged neighbourhoods.

7.5 Recommendations for Future Research

The potential for spatial and temporal research after the Canterbury earthquakes is vast. Outlined below are just a few of the potential research topics which could be undertaken to expand on the findings of this thesis.

A potential research topic for future research would be to undertake a similar study at future points in time. Existing literature indicates that there may be long term effects on anxiety after an earthquake Armenian et al., 1998, however the Canterbury earthquakes offer unique characteristics for a longitudinal study given the frequency and intensity of aftershocks.

This thesis has focussed on quantitative research methods. A future research topic could be to use a mix of qualitative and quantitative research methods to examine the spatial and temporal patterns of anxiety and chest pain after an earthquake. The Canterbury earthquakes have been well recorded, and a potential data set that could

be useful to examine spatially is the University of Canterbury's seismic digital recordings.

The findings of this thesis highlight the need to track population movement of households within the CDHB region. After the 2010 Haiti earthquake, Bengtsson, Lu, Thorson, Garfield, and von Schreeb (2011) tracked population movement immediately after the earthquake using mobile phone network data. Given the size of Christchurch, and that it is not a third world country like Haiti, a different approach to population movement tracking is required. The population movement data of the month and years following the earthquakes could be used with individual level data on anxiety and chest pain to further explore the spatial and temporal patterns of anxiety and chest pain as a result of the Canterbury earthquakes.

Other measures of health outcomes and measures of earthquake damage could also be examined to explore spatial and temporal patterns after the Canterbury earthquakes. Other measures of earthquake damage could include accessibility to transport. Many roads were damaged as a result of the earthquakes, and public transport was limited. Future research could look at whether transport restrictions as a result of the earthquakes impacted people's ability to access the hospital and whether this varied by deprivation levels.

7.6 Summary

The primary purpose of this thesis was to understand the spatial and temporal patterns of anxiety and chest pain after the Canterbury earthquakes. Spatial clusters of anxiety and chest pain were identified across Christchurch at the time of the two most damaging earthquakes; however these clusters excluded some CAUs which suffered the most damage. The analysis also found that liquefaction was a stronger indicator of anxiety than CERA red-zones. These findings suggest that areas with

the highest levels of damage may not suffer as much anxiety and chest pain related health outcomes as those with low to moderate damage. Further analysis of other health variables at an independent level, damage variables, as well as the tracking of populations is required to eliminate any confounding variables which may have influenced the findings of this thesis. This thesis has also found a temporal relationship between anxiety, chest pain and when an earthquake occurred. Anxiety increased one month after an earthquake, and chest pain peaked two weeks after an earthquake and then gradually decreased over the following five weeks.

The thesis concludes that there are spatial and temporal variations within anxiety and chest pain after the Canterbury earthquakes. However, further research is suggested to eliminate further confounding variables, as well as to identify the patterns at a finer scale. This thesis, combined with future research will be able to be used to plan for future events similar to the Canterbury earthquakes, and ensure that resources are targeted at the people who need them most.

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Appendices

Appendix 1- RHISE Data User Agreement

RHISE DATABASE – DATA ACCESS USER AGREEMENT (*DAUA*)

Effective Date: 26th day of April 2012

Parties

- A. Kimberley Reed (the *Researcher*)
- B. Professor Michael Ardagh (the Rhise Database Project Group on behalf of the *Canterbury District Health Board*)

Background

1. The Rhise Database Project Group was formed following the 22 February 2011 earthquake and has established a database of the individuals who were injured/became ill as a result of that earthquake (the *Database*). The Rhise Database Project group is hosted by the Canterbury District Health Board (CDHB) and the database is housed in and managed by the CDHB. The Database will be expanded to collect data on people injured or unwell following the September 2010, June 2011 and December 2011 earthquakes.
2. The Researcher wishes to perform an analysis which utilizes the Database.
3. The Researcher has presented a preliminary data request to the Rhise Database Project Group for access to the Database.

It is agreed as follows:

1. **Privacy.** Personal Health Information (*PHI*) held on the Database will not be provided except in a de-identified format unless ethical approval has been gained to access an identified dataset.
2. **Use of Limited Dataset.** This Agreement authorizes the Researcher to request a Limited Data Set from the Database only for the purpose(s) stated in the Preliminary Data Request. No other use of the Limited Data Set is permitted and use of this Database for other reasons or analyses other than those dictated in the approved Preliminary Data Request shall be considered a breach of contract.
 - a) **PHI.** Researcher shall *not* receive or store PHI except for the PHI identified as the LIMITED DATA SET variables, when the use of these variables is dictated by the nature of the research analysis being performed.

The Rhise Collaborative Database Access & User Agreement
Version 2.0, dated 21st March 2012


Page 1 of 1

(180) days post the effective date or until terminated by applicable law or regulation. The Rhise Database Project Group may terminate the Agreement at its discretion by written notice to the Researcher. Upon termination of this Agreement, the Researcher must certify in writing that all data from the Limited Data Set have been deleted and are no longer in use by the Researcher.

IN WITNESS WHEREOF, the Parties have executed this Data Access User Agreement as of the day and year first set forth above.


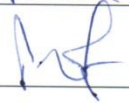
Researcher

By: Kimberley Reed
Name


Signature

MGIS student at Canterbury University
Title

A member of the Rhise Database Project Group on behalf of the Canterbury District Health Board

By: 
Name

Title


Signature
26/4/12

Appendix 2- New Zealand Health and Disability Ethics Committee Approval



Health and Disability Ethics Committees
1 the Terrace
PO Box 5013
Wellington
6011

0800 4 ETHICS
hdec@mh.govt.nz

16 November 2012

Miss Kimberley Reed
GeoHealth Laboratory, Department of Geography, p
University of Canterbury,
Private Bag 4800
Christchurch 8140

Dear Miss Reed

Re:	Ethics ref:	12/STH/38
	Study title:	Spatial and Spatio-Temporal Variation of Anxiety as a Result of the Canterbury Earthquakes

I am pleased to advise that this application has been approved by the Southern Health and Disability Ethics Committee. This decision was made through the HDEC-Expedited Review pathway.

Conditions of HDEC approval

HDEC approval for this study is subject to the following conditions being met prior to the commencement of the study in New Zealand. It is your responsibility, and that of the study's sponsor, to ensure that these conditions are met. No further review by the Southern Health and Disability Ethics Committee is required.

Standard conditions:

1. Before the study commences at any locality in New Zealand, all relevant regulatory approvals must be obtained.
2. Before the study commences at a given locality in New Zealand, it must be authorised by that locality in Online Forms. Locality authorisation confirms that the locality is suitable for the safe and effective conduct of the study, and that local research governance issues have been addressed.

After HDEC review

Please refer to the *Standard Operating Procedures for Health and Disability Ethics Committees* (available on www.ethics.health.govt.nz) for HDEC requirements relating to amendments and other post-approval processes.

Participant access to ACC

The Southern Health and Disability Ethics Committee is satisfied that your study is not a clinical trial that is to be conducted principally for the benefit of the manufacturer or distributor of the medicine or item being trialed. Participants injured as a result of

treatment received as part of your study may therefore be eligible for publicly-funded compensation through the Accident Compensation Corporation (ACC).

Please don't hesitate to contact the HDEC secretariat for further information. We wish you all the best for your study.

Yours sincerely,

A handwritten signature in black ink, appearing to read 'Raewyn Idoine', written over a horizontal line.

Ms Raewyn Idoine
Chairperson
Southern Health and Disability Ethics Committee

End: appendix A: documents submitted
appendix B: statement of compliance and list of members

Appendix 3- ACC Ethical Approval

10 September 2012

Kimberley Reed

GeoHealth laboratory

University of Canterbury

CHRISTCHURCH

Dear Ms Reed

ACC Research Ethics Committee Decision Notification

Re: Spatial and Spatio-temporal variation of Mental Injury as a result of the Canterbury Earthquakes, Kimberley Reed, University of Canterbury, #218

Thank you for your research proposal re-submission which was considered by the ACC Research Ethics Committee at its meeting on 5 September 2012.

The Committee noted that there may only be a small number of Mental Injury claims in the ACC data. Also the use of residential address for the study could be unreliable due to numbers of people moving location or not living at their residential address.

However, your research proposal was approved by the Committee on the basis of provision of ACC claims for Mental Injury which will be based on the residential address of clients rather than the location of injury.

Please do not hesitate to contact me if you have any queries.

Yours sincerely

Fiona Conlon, Secretary

PP Alison Douglass, Co-Chair

ACC Research Ethics Committee