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Updated Hazard and Risk Analysis for the Wellington Region CDEM Group Plan

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1. Introduction

This report is an updated, revised and expanded version of the Hazard and Risk Analysis for the Wellington Region CDEM Group Plan. More detailed background information has been provided in the hazard event summaries to give a better context for understanding the particular hazards. This has enabled the likelihood and scenarios sections to be updated. The hazard summaries also include recent research published in journals and in reports commissioned by Greater Wellington, City and District Councils in the region and central government agencies such as EQC, MfE and MCDEM. The hazard summaries were prepared with the latest available information, but gaps in the knowledge still exist. A better understanding of the hazard risk and consequences exists in some areas than others. The state of knowledge is continually improving and the summaries will be updated as new information comes to light.

2. Background and Process

The aim of the first report was twofold. First, to outline the process used to assess the hazards and the level of risk that these hazards pose to the Wellington Region. Second, to provide this information in a single report for the Civil Defence Emergency Management Group. This was the first step in developing the strategic direction of the CDEM Group Plan (The Plan). The process involved:

- Developing a common understanding of the hazards and risks by all agencies with a CDEM role
- Identifying the hazards and risks that the Group will manage (as opposed to those to be managed by individual agencies). This is a requirement under Section 49 (2)(b) of the CDEM Act 2002.
- Identifying the hazards that are of national significance. The Director of CDEM needs to know this to meet Section 8 (2)(b) of the CDEM Act 2002.
- Facilitating the identification of issues to be addressed by the Plan. This ensured that sound hazard and risk information was used in the development of the Plan.

2.1 Hazard and Risk Analysis Workshops

Small group workshops were held to discuss each hazard from 4-24 November, 2003. Invited participants represented a variety of agencies to ensure a mix of perspectives and understanding of the hazard. At each of these workshops, participants reviewed the hazard event summaries and made additions where necessary. The key outcome of these workshops was the identification of issues to be addressed by the Plan that arose from the hazard and risks being discussed. A final workshop of all agencies with a CDEM role was held on 9 December, 2003, where the results of the smaller workshops and the hazard and risk rating were presented. Additional issues were identified and the hazard and risk ratings were confirmed.

2.2 Hazard and Risk Rating

The key principles emphasised during the hazard and risk analysis were:

- The focus of the analysis was on the hazards and risks that the CDEM Group would need to be involved in managing. Therefore hazards that could be managed by one agency or within one geographic jurisdiction were not considered in this process.

- The focus of the analysis was on hazards and risks that would require some management under the CDEM Act 2002. This did not necessarily mean that there needed to be an emergency declaration under the Act for the CDEM Group to be involved. Hazards and risks that were wholly managed through other legislation were not considered in this process (e.g. some agricultural and biological hazards).

- The final and most important product of the hazard and risk analysis was the identification of issues for the CDEM Group Plan. Hazard and risk summaries and ratings were used as tools to focus the process of issue identification. Hazard summary information was prepared at a level that could be easily understood by all agencies with a CDEM role.

- Hazard and risk ratings were allocated based on the maximum likely scenario for each hazard. For some hazard groupings more than one scenario was rated due to the significant differences between possible scenarios within the hazard grouping.

3. Hazard Event Summaries

Hazard summaries were developed for events that could require CDEM Group involvement. Feedback about the content and format of these summary sheets was sought from hazard information providers and the Ministry of Civil Defence Emergency Management.

Ratings were assigned to each hazard. Where a particular hazard had more than one major mechanism it was assessed separately for each scenario.

Ratings were allocated for:

- Likelihood
- Consequences
- Initial Risk Rating (likelihood x consequence)
- Seriousness (Human, Economic, Social, Infrastructure, Geographic)
- Manageability
- Urgency
- Growth

The reasons for assigning the ratings were to:

- Ensure that all aspects of the hazard and risk were considered
- Provide a method of comparing the hazards and risks on similar scales
- Determine gaps where information was missing
- Determine if there were any hazards that need to be addressed with a higher priority than others
- Facilitate discussion about all aspects of the hazard so that the full range of issues could be identified.

The ratings allocated and system used is included in Appendix 1.

3.1 Earthquake

3.1.1 Hazard Context/Description

The Wellington region is located within an area of high seismicity near the plate boundary of the Pacific and Australian tectonic plates. In geological terms this boundary is referred to as the Hikurangi Subduction Margin and is where the Pacific Plate is subducting beneath the Australian Plate. The Subduction Margin edge is located some 35 km offshore from Cape Palliser, but inclines or dips northwest on an angle, so that the lower margin sits beneath Wellington at a depth of around 30 km. In terms of potential loss (both economic and social) from earthquakes, the Wellington metropolitan area is the most at-risk population centre in New Zealand.

Stresses in the earths crust produced by the subduction margin have produced a number of faults, both on land and on the seafloor, around the Wellington Region. Many of these faults are still active and present a significant hazard. The five faults that could potentially cause the most damage are; the Wellington Fault, Ohariu Fault (north & south), Wairarapa Fault, Carterton Fault and the Masterton Fault. In addition, the subduction interface could produce a large and devastating earthquake, but little is currently known about the characteristics of fault movements on this feature. A number of these faults have an offshore component, that adds an additional tsunami risk to a rupture event. All the population centres in the region (Wellington City, Hutt Valley, Porirua, Kapiti Coast, Wairarapa settlements) encompassing around 450,000 people, are within 10 km of one of these active faults. Of this number, approximately 75% are within 10 km of the Wellington Fault.

Earthquakes can be described in different ways. *Magnitude* measures the energy released in the earthquake or its *size*. This is the number often reported in the news after an earthquake. It is calculated on the Richter Scale, which is exponential. Each increment is 30 times more powerful than the preceding level. For example a magnitude 6.0 earthquake releases 30 times more energy than a magnitude 5.0 event. *Intensity* is the amount of ground shaking and damage at a particular location, and is usually measured with the Modified Mercalli (MM) intensity scale. In New Zealand there are 10 gradations, with I being an earthquake that is only felt by a few people, through X where there is widespread catastrophic damage. Intensity at a given point depends on the magnitude of the earthquake, geographic location (epicentre/focus/distance) and substrate composition (rock/soil/sand/artificial fill). The depth of an earthquake has an important bearing on how it affects groundshaking. Earthquakes less than 40 km deep are considered shallow and have a far greater potential to cause severe damage. In addition the ground through which the earthquake travels affects the wave propagation. Rock effectively dampens down earthquake shaking, whilst loose or soft substrates such as sands and gravels can amplify ground motion.

Earthquake hazards include ground shaking, liquefaction, surface fault rupture, landslides and tsunami. This section covers ground shaking, liquefaction and surface fault rupture. Landslides and tsunami are covered separately.

(a) Recent Large Events

The epicentres of earthquakes greater than magnitude 2 recorded in the central New Zealand region between 1997 and 2007 are shown in Figure 3.1.1. There is a general pattern of shallow earthquakes (less than 40 km deep) through Hawke's Bay, Manawatu, Wairarapa, Wellington and Marlborough, and deeper earthquakes from Taranaki to Nelson, linked to the subducting Pacific Plate.

Since 1997, twelve earthquakes have caused significant damage in the region (defined here as prompting more than 30 damage claims to the Earthquake Commission [EQC]). These 12 earthquakes have together prompted almost 3000 damage claims to EQC, with payouts totalling almost $3 million. Epicentres of these earthquakes are shown in Figure 3.1.2, and details are given in Table 3.1.1. Significantly, it can be seen that four of these originated outside the region. The earthquake that prompted the most claims was a 31 km deep, M5.5 event near Upper Hutt on 21 January 2005. EQC claims for the Wellington region totalled over $1.3 million. The damage it caused provides a good reminder that even moderate magnitude earthquakes can cause significant damage if they occur at shallow depths under urban areas.

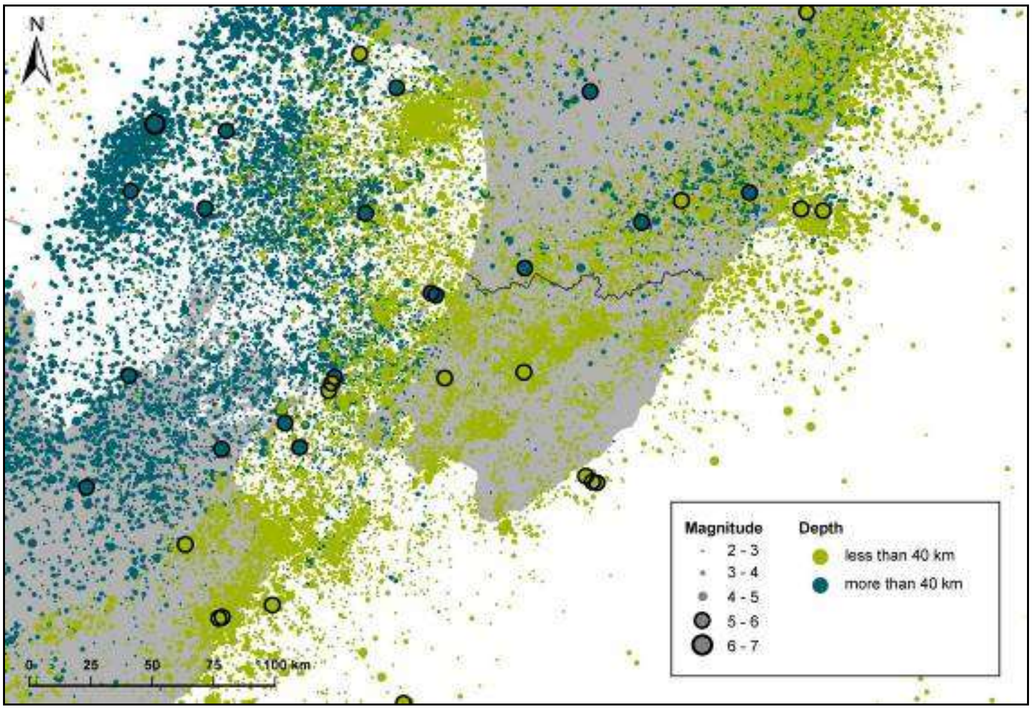

Figure 3.1.1. Epicentres of earthquakes >M 2.0 between July 1995 and June 2007 (data from GeoNet).

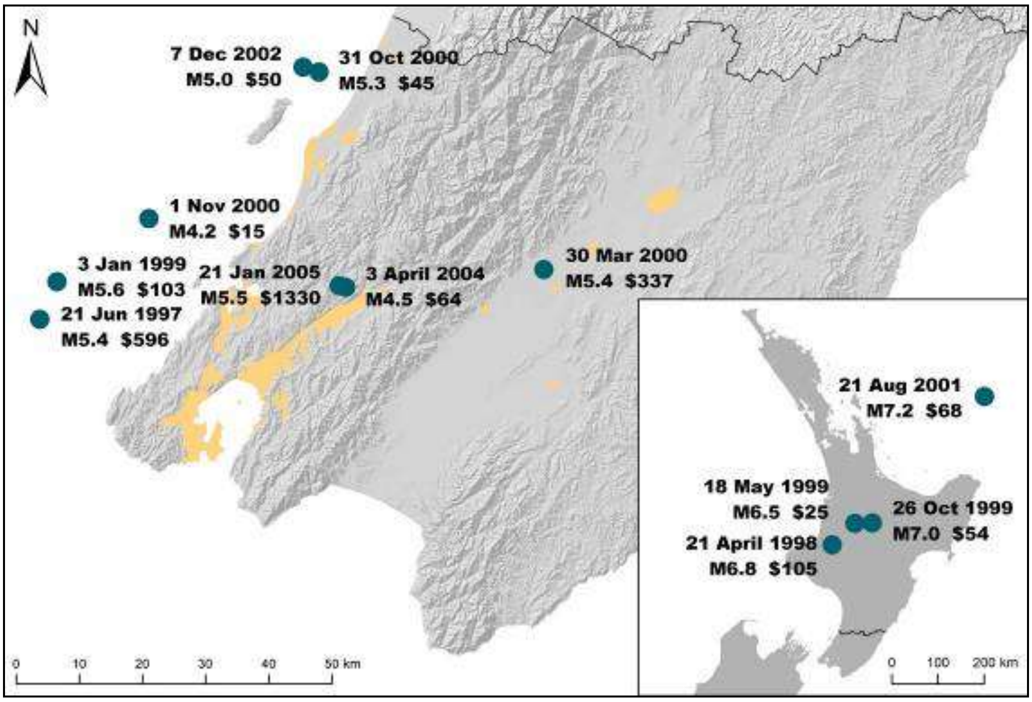

Figure 3.1.2. Epicentres of earthquakes generating more than 30 EQC claims in the Wellington region between 1997 and 2007, with the date, magnitude and the dollar amount (in 1000s) of EQC claims paid out in the region (source: GeoNet, Earthquake Commission).

Table 3.1.1. Earthquakes generating more than 30 EQC claims in the Wellington region between 1997 and 2007 (source: GeoNet, Earthquake Commission).

Date	Magnitude[1]	Depth (km)	EQC claims[2]	Amount paid out ($)[2]
21 June 1997	5.4	37	712	595,894
21 April 1998	6.8	232	237	105,310
3 January 1999	5.6	58	180	103,348
18 May 1999	6.5	264	42	24,724
26 October 1999	7.0	161	70	53,539
30 March 2000	5.4	31	498	336,777
31 October 2000	5.3	55	56	45,392
1 November 2000	4.2	39	35	15,194
21 August 2001	7.2	33	70	68,133
7 December 2002	5.0	47	39	49,758
3 April 2004	4.5	29	40	63,820
21 January 2005	5.5	32	956	1,330,900
			2935	**2,792,789**

[1] Local magnitude
[2] EQC claims and amounts paid out in the Wellington region (does not include claims from other regions)

(b) Major Active Faults in the Wellington Region

A number of active faults in the region could produce large, destructive earthquakes, resulting in hundreds of deaths, thousands of injuries and billions of dollars worth of damage. A considerable amount of research has been commissioned by Greater Wellington over the past ten years to identify and classify faults in the region. There is still considerable uncertainty about the recurrence intervals and faulting characteristics for many of the faults, but research into these is ongoing and improving over time. The geographic extent of these faults can be seen in Figure 3.1.3.

Most of the active faults in the region are right-lateral, strike-slip faults. They have average lateral slip rates that range from 1-10 mm/yr and average rupture recurrence intervals of 500-5000 years. Through a combination of historical, paleoseismic and geomorphic studies there is a near complete record of the last 1000 years of faulting events for the region and a growing record of older events. In the last 1000 years there has been one surface-faulting event on the Wairarapa fault (1855); two on the Wellington Fault (300-350 & 720-780 B.P.); and one on the Ohariu Fault (1050-1000 B.P.). The basic characteristics of these faults are given in Table 3.1.2.

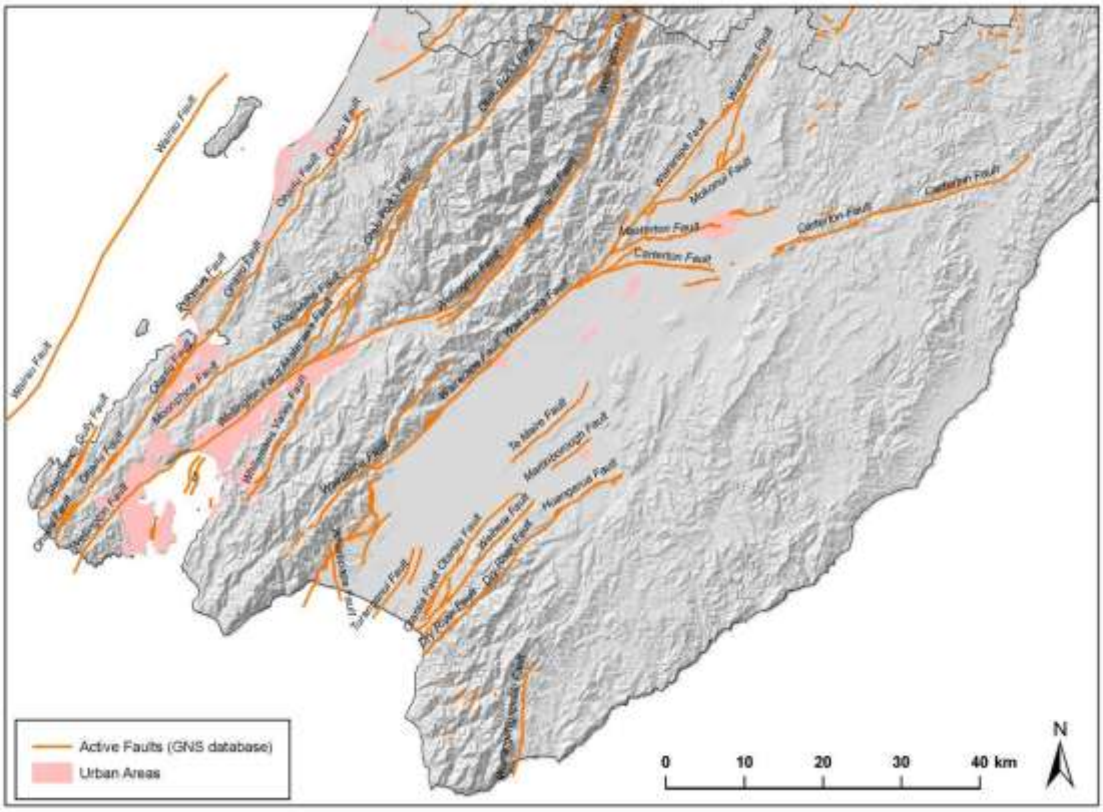

Figure 3.1.3. Active faults in the Greater Wellington Regional Council administrative region.

Table 3.1.2. Active fault earthquake sources in the Wellington region.

Fault	Recurrence Interval (yrs)	Elapsed time since last event (yrs)	Maximum Magnitude[1]
Wellington	~ 900	~ 300	7.6
Ohariu	2200	1050 - 1000	7.6
North Ohariu	1500 - 3500	~ 1000	7.3 - 7.7
Wairau	1000 - 2300	> 800	7.2-7.7
Gibbs	3500 - 5000	<10,000	~ 7.0
Shepherds Gully	2500 - 5000	~ 1200	7.6
Pukerua	2500 - 5000	~ 1200	7.6
Otaki Forks	3500- 5000	unknown	7.3 - 7.6
Akatarawa	3500 - 9000	<10,000	> 7.0
Wairarapa	~ 1200	152	8.3
Dreyers Rock/Kowhai	<2000	152?	8.0
Mokonui	1300 - 2000	1100-2600	6.7
Masterton	~ 1000	unknown	6.7
Carterton	700 -1000	unknown	7.0
Cross Creek	2000 - 3500	unknown	?
Wharekauhau Thrust	<2000	152	8.0
Battery Hill	<2000	152?	8.0
Otaraia	3500 - 5000	unknown	?
Martinborough	5000 - 10000	unknown	~ 7.0
Huangarua/Dry River	3500 - 5000	unknown	8.0
Wairangi/Ngapotiki	1000 - 3200	unknown	?
Boo Boo (offshore)	500 - 2000?	unknown	7.2 - 7.6
Subduction Interface	500 - 2000?	unknown	7.9-8.4 (8.2)

[1] Estimated earthquake magnitude able to be generated in a penultimate faulting event.

The Wellington Fault is one of the major active strike-slip faults of the Southern North Island and presents a significant seismic hazard to the Greater Wellington area. The Fault has three segments that all trend in a northeast direction; the Wellington-Hutt, Tararua and Pahiatua-Woodville segments. The Wellington-Hutt segment extends from Cook Strait through Long Gully, Karori, Thorndon and the Hutt Valley. Around Pakuratahi-Kaitoke, the fault side steps 2 km to the east where it enters the Tararua Range. This forms the start of the Tararua segment that continues through the Wairarapa. The Pahiatua-Woodville segment continues northward from around Eketahuna to where it terminates at Woodville.

The Wellington-Hutt Valley segment of the fault is thought to move on average every 900 years. Until recently it was thought this was the most likely fault in the region to next move because the elapsed time since the last rupture event was close to its average recurrence interval. However, research findings from the It's Our Fault project have downgraded the recurrence interval of the this fault rupturing every 500-750 years to approximately every 900 years. The research also found the Wellington-Hutt segment last moved around 300 years ago producing an estimated magnitude 7.6 earthquake. When it ruptures it produces significant lateral and vertical coseismic displacement. A flight of terraces at Te Marua indicate that the five last rupture events produced lateral displacements averaging 4.0 ±0.3 m. Currently it is thought that vertical displacements may be in the order of 1-2 m. It is possible that Lower Hutt will be downthrown and experience subsidence in the next earthquake. In the event that this fault ruptured, it would cause severe, catastrophic damage in the Lower North Island, particularly in the Wellington and Hutt Valley metropolitan areas.

Research on the Wellington Fault and its various sections is ongoing. Currently, GNS Science is coordinating a multi-million dollar, 5 year research programme into the Fault, called the 'It's Out Fault' project. An important outcome of this research will be an assessment of the effects of a large fault rupture. Another area of research on the Fault concerns the relationships between these segments, in particular the way in which movements on one segment stress or de-stress the other segments. The findings from the work have shown that the 1855 Wairarapa earthquake de-stressed the Wellington-Hutt Fault segment and downgraded the risk of fault rupture by several hundred years. However, the findings also indicate that the Wairarapa Fault is more active than previously thought and the average recurrence has been shortened. Greater Wellington is currently working with WELA and GNS to commission a report into the effects a rupture on the Tararua segment would have in the Wairarapa.

The Ohariu Fault is another major earthquake generating fault in the Wellington region. It is a long and active fault that extends 70 km in a northeast direction from Cook Strait, through Tongue Point, the Makara catchment, Ohariu Valley, Porirua and up the Kapiti Coast to at least Waikanae. North of Waikanae, it is thought to have a second segment referred to as the northern Ohariu Fault that extends some 60 km from Otaki to Palmerston North. Recent work has upgraded the recurrence interval on this fault to a greater degree of accuracy. The work indicates that the fault moves on average every 2200 years producing a large (~ 7.5) magnitude earthquake with about 3-5 m of displacement. It is thought to have last ruptured around 1000 years ago. Previous estimates ranged from 1500-7000 years.

The Wairarapa Fault is also a significant earthquake source, capable of producing magnitude 8.0+ earthquakes. The fault extends northeast from Cook Strait through the western edge of Palliser Bay, Lake Wairarapa and along the range front of the Tararua foothills, west of all the major settlements and terminating north of Mauriceville. In 1855 this fault ruptured in event known as the Wairarapa earthquake. The fault ruptured the surface along a 75 km stretch from Lake Wairarapa to Mauriceville causing 12.0 m of right lateral displacement at the ground surface. The entire Wellington region was titled westward and approximately 5000 km^2 of land was vertically uplifted. There was 0.3 m of uplift at Makara, between 1-2 m of uplift around Wellington and over 6.0 m at Turakirae Head. This was a penultimate faulting event (PFE). For many years the earthquake was estimated to have had a magnitude of approximately 7.9-8.0. However, more recent work indicates that it was at least M8.2, making it the largest earthquake in New Zealand since European settlement. The Modified Mercalli shaking intensity in the Wairarapa is thought to have been at least 10 – the maximum possible. Although it is unlikely to rupture again in the next few hundred years, recent research indicates that this is an extremely active fault and may be moving faster than previously thought. Findings from the It's Out Fault project have reduced the recurrence interval on this fault from 1600 years to 1200 years.

The Masterton and Carterton Faults both splay off the Wairarapa Fault in an easterly direction and run through the two largest urban settlements in the Wairarapa. Both faults have an undefined middle section where the surface expression of the fault has been obscured by erosion and sedimentation from the Ruamahanga, Waingawa and Waipoua Rivers. This creates considerable uncertainty in locating their exact positions for planning purposes, especially in Masterton, where the fault runs through the middle of the town. Considerable work has been conducted into both the Carterton Fault and Masterton Faults. Both Faults are considered to be active with recurrence intervals in the order of 1000 years. It is not known when they last ruptured, but there is some indication that there was an event on the Masterton fault around 800 years ago.

The presence of a subduction interface beneath Wellington is well established by seismological studies, but its risk potential is poorly understood. One of the main reasons for this lack of knowledge is that there have been no historic large earthquakes unequivocally originating from the interface. It is also unknown how much strain the subduction margin is able to accommodate and to what degree the plates are locked. It is known that the plates are moving at around ~ 28 mm/yr and that about half of this is resulting in deformation of the upper crust, producing structures such as the Tararua Range. However, this leaves the remaining movement, about 15 mm/yr, to be taken up as strain on the subduction interface. Modelling indicates that a rupture event could occur along 60 km of the interface, producing 8-15 m of displacement in a M7.9-8.4 earthquake, with the best estimate being M8.2. The estimate of the recurrence interval for an event of this magnitude is in the order of 2000 years.

(c) Associated Earthquake Effects

Surface fault rupture

Earthquakes are caused when stresses that have built up on a fault are released. Often the fault movement occurs at great depth and there is no deformation on the surface. However, in a sufficiently large and shallow earthquake the fault movement may cause vertical uplift/downthrust or horizontal/lateral movements that deform the ground surface. In these events the ground along the fault often ruptures along the surface physically tearing the ground. This can affect land within about 50 m of a fault. Ministry for the Environment guidelines recommend a building avoidance zone of 20 m either side of an active fault. In conjunction with Greater Wellington, city and district councils are in the process of identifying active faults and putting in place hazard zones or alerts around these features.

Ground shaking

Ground shaking is the most severe widespread effect of an earthquake and is usually most severe closest to the fault. When a fault ruptures a large amount of energy is released. This energy travels through the ground in the form of waves at extremely high velocity (up to 25,000 km/h). As these waves travel through the ground they produce a shaking effect. In addition, when these waves reach the ground level, they slow down and are transformed into surface waves that produce either a vertical or lateral movement. This ground movement is especially damaging. In loose unconsolidated sediments such as gravels, sands and silts, ground shaking effects can be amplified. Figure 3.1.4 shows known areas within the Wellington region where ground shaking is likely to be amplified in an earthquake, based on surface geology. Areas likely to experience the highest amplification include, reclaimed land around central Wellington, Kilbirnie, Rongotai and Miramar, Petone, Lower Hutt, Wainuiomata, Mangaroa Valley and low lying areas around Porirua Harbour and Pauatahanui. Areas of likely amplification in the Wairarapa include areas around Masterton, Carterton and Lake Wairarapa.

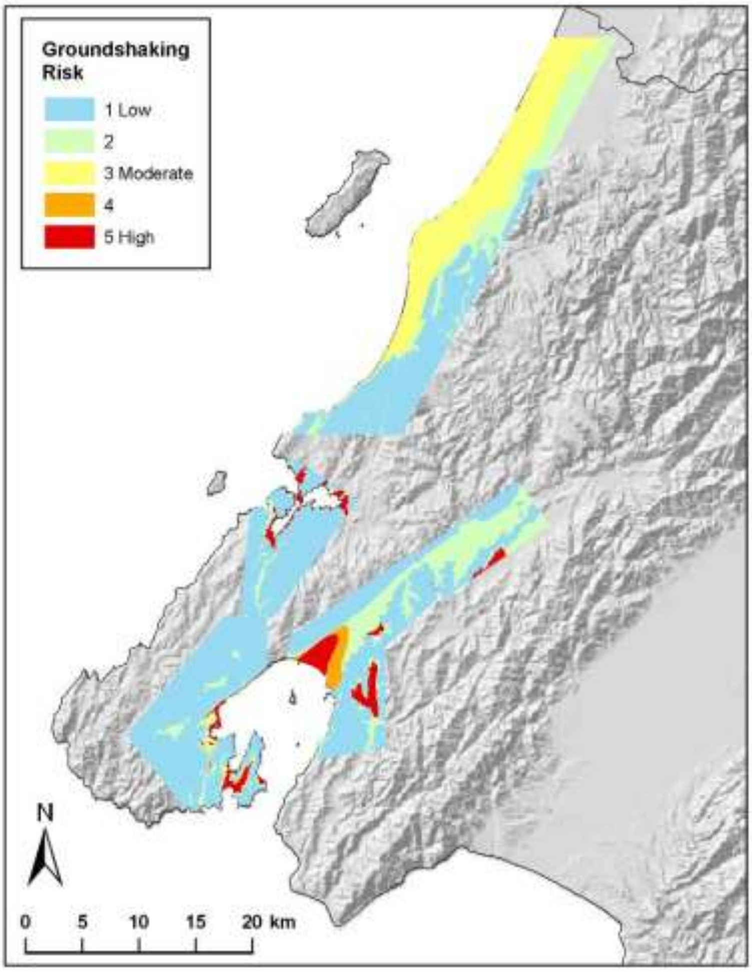

Figure 3.1.4. Ground shaking risk in the major urbanised areas of the Wellington region.

Liquefaction

Liquefaction occurs when unconsolidated soils, particularly silty and sandy soils, become saturated with water in a shaking event and behave more as a liquid than a solid. Essentially the ground looses its shear strength, causing buildings to subside or collapse during an earthquake. Liquefaction has a range of associated effects and may cause any of the following:

- Ground subsidence
- Lateral spreading

- Landslides on moderate slopes
- Foundation failures
- Flotation of buried or partially buried structures e.g. piles
- Water fountaining and sand boils

Liquefaction can occur when ground shaking intensities exceed MM VII. Places susceptible to liquefaction are usually low lying areas, close to water that have a fine, unconsolidated substrate. Reclaimed land around harbours, lakes and waterways is particularly at risk. Figure 3.1.5 shows the liquefaction potential within the Wellington region, based on surface geology. Areas at risk in the Wellington region include reclaimed land around Wellington City; Hutt River mouth and lower floodplain (Petone, Seaview, Gracefield); Porirua CBD and Pauatahanui; low lying areas on the Kapiti coast; land around Lake Wairarapa; areas built on reclaimed watercourses or swamps (Wainuiomata, Miramar peninsular interior, Kilbirnie).

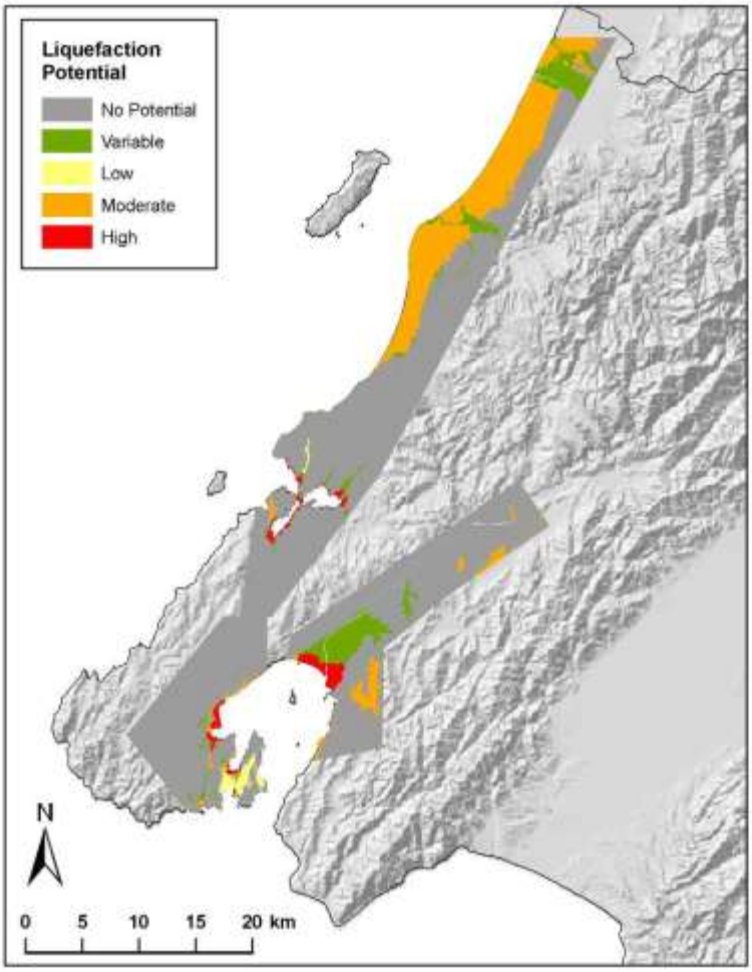

Figure 3.1.5. Liquefaction potential in the major urbanised areas of the Wellington region.

3.1.2 Scenarios

Maximum probable event

A shallow focus earthquake, magnitude 7.0 + on the Wellington fault. Lateral displacement of 5-10 m and 1-2 m vertical in parts of the Hutt Valley, with potential subsidence in Lower Hutt. Liquefaction in areas of Lower Hutt, Wellington waterfront and port area and around Porirua Harbour. Amplified ground shaking causes severe damage in these same areas. Harbour seiching for 24-48 hours and potential for a 1-2 m locally generated tsunami, flooding low lying areas around Wellington Harbour. If subsidence occurs in Lower Hutt, Petone, Seaview, Gracefield will be particularly at risk from inundation. Probably 1-2 large aftershocks of M 6.0+ that cause further collapse to already damaged structures and numerous smaller aftershocks. High risk of fires in urban and suburban areas, that have potential to cause widespread damage if unable to be brought under control. It is possible that fire may breakout in over 30 commercial and over 50 domestic premises. Access into and within the region will be severely affected and initially may only be possible by helicopter. The airport will probably be unusable and will require immediate work to allow aircraft such as C-130 Hercules to land. Road and rail networks will potentially be severely damaged and cut by landslides and rockfall. Utilities (power, water, sewerage, gas) will probably all be cut and may take weeks to months to restore. Initially, fatalities may number in the 100's and injuries in the 1000's, with potential for this increase due to fire, aftershocks and tsunami. 1000's of buildings sustain minor to moderate damage and a number of major structural collapses. 1000's of people made homeless. Emergency and medical services will be severely stretched and will require assistance from national and possibly international response teams. Adjacent regions will also be affected, particularly the Wairarapa.

Mid-range event

Magnitude 6.0 - 6.9 event on any fault near a metropolitan area anywhere in the region (Masterton, Porirua, Paraparaumu, Upper Hutt, Hutt City, Wellington). Considerable light to moderate damage might be expected from this event, especially close to the epicentre. Unreinforced stone and brick walls will crack and may collapse – historic buildings are particularly at risk, chimneys, parapets and architectural ornaments may topple, windows may smash and unrestrained water cylinders/fittings/furniture will fall over. A small number of building collapses might be expected from events over M 6.7. Utilities may be disrupted. Generally the damage will be repairable. A significant number of people will be injured, but medical and emergency services will be able to cope without too much difficulty.

3.1.3 Likelihood

Around 400 earthquakes occur in the Wellington region every single year and since 1855 there have been over 60,650 earthquakes. Most of these are very small (< M3.0) and have no effect on the built environment. A record of the past 152 years of earthquakes can be seen in Figure 3.1.6. The average earthquake is M 2.3 and occurs at a depth of 30 km. Table 3.1.3 provides the numeric values in each of the frequency intervals and gives an average recurrence interval for the magnitude classes. The record is too short to estimate recurrence intervals for magnitude 7.0+ events, but it is sufficient to provide an indication of return periods for earthquakes smaller than this. Of note, is that magnitude 5-5.99 earthquakes have a 2 year return period and magnitude 6-6.99 earthquakes occur on average every 20 years. The last earthquake of this size was 17 years ago on May 13, 1990.

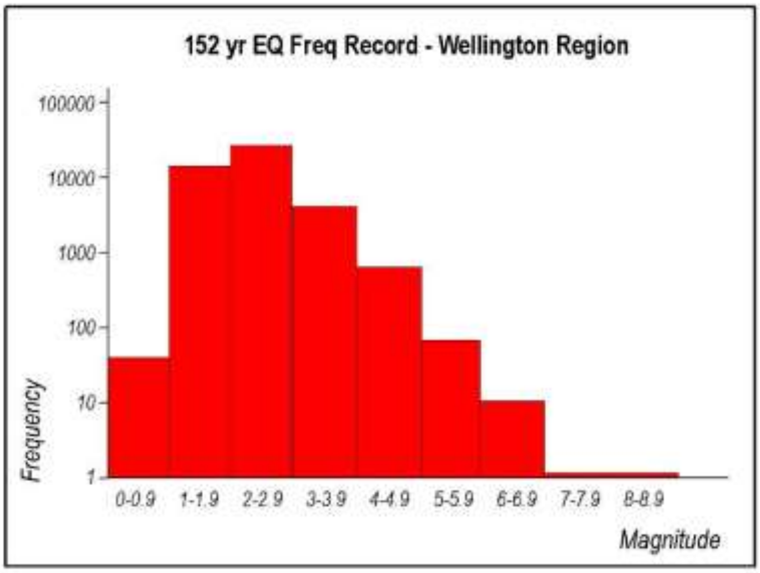

Figure 3.1.6. Frequency histogram of earthquake events originating in the Wellington region since 1855.

Table 3.1.3. Return periods for earthquakes in the Wellington region based on 152 years of recordings. *NB.* Recording period is too short to provide accurate recurrence intervals for M 7.0 + earthquakes.

Magnitude	***N*** **events since 1855**	**Recurrence Interval (yrs)**
0 - 0.99	44	3.5
1 - 1.99	19469	0.008
2 - 2.99	34763	0.004
3 - 3.99	5072	0.03
4 - 4.99	812	0.2
5 - 5.99	78	**1.9**
6 - 6.99	10	**15.2** (19)*****
7 - 7.99	1	152+ (500)#
8 - 8.99	1	152+ (1000)#
9 - 9.99	0	---

* Return period with 1942 M6.0 cluster included as one event.
# Actual return periods based on geological evidence.

Another way of expressing earthquake risk is to model the ground shaking intensity for different parts of the region that might be expected from a large earthquake. This type of “probabilistic” modelling takes into account the characteristics (location, earthquake size, recurrence interval) of all potential earthquake sources (faults), and calculates how often a particular intensity of ground shaking will be felt on average at a particular site.

Figure 3.1.7 shows the shaking intensity modelled for a 1000 yr event in the Wellington region based on historical evidence. The expected return periods are given in Table 3.1.4. It can be seen that the average recurrence interval for a severe shaking event in the Wellington region is estimated to be 500 years for MM IX. This corresponds to a penultimate faulting event on the Wellington Fault as outlined in the scenario above. In the Wellington region, the maximum probable earthquake magnitudes that can be generated on the active strike slip faults are all quite similar. Thus, proximity to a fault and its recurrence interval are key elements in determining the hazard risk at a particular site. The level of shaking hazard approaches near maximum values within a return time of ~500 years, largely reflecting the recurrence interval (500-770) of surface rupture earthquakes on the Wellington Fault.

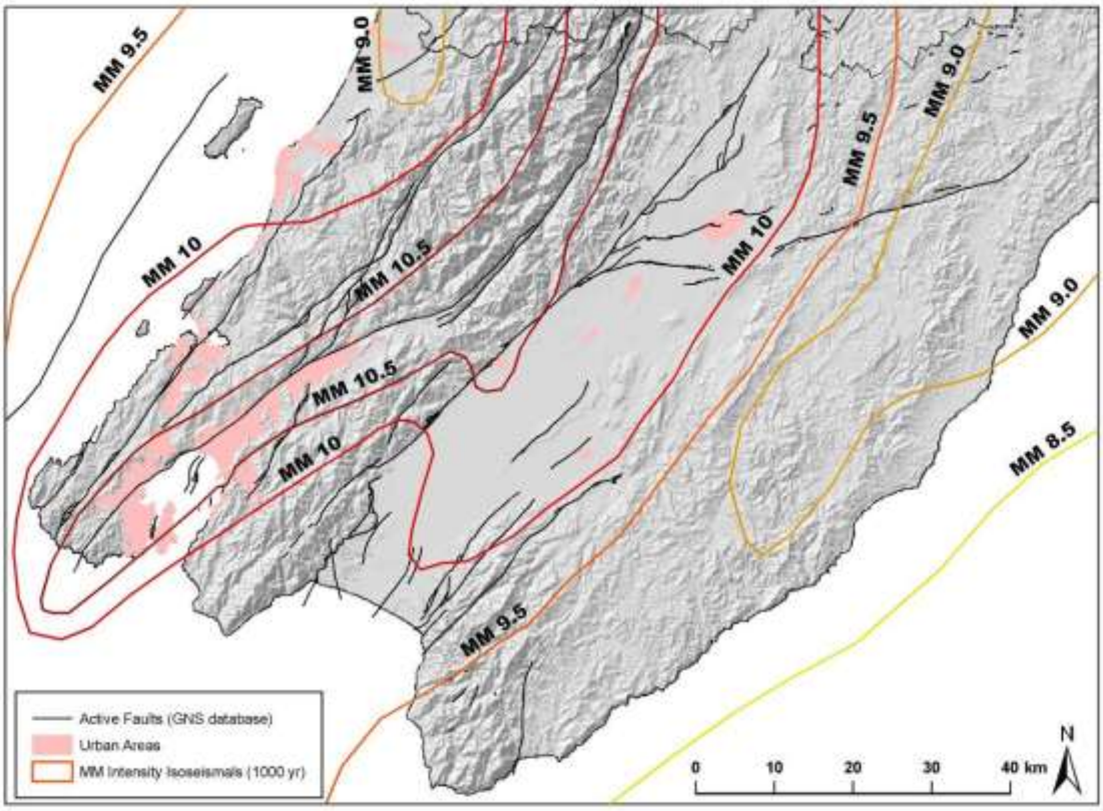

Figure 3.1.7. Modified Mercalli isoseismal model for a 1000 yr event in the Wellington region based on historical seismicity and maximum fault hazard defined by probable maximum event magnitude and recurrence interval for the main active faults in the region.

Table 3.1.4. Expected ground shaking intensity return periods for a bedrock site in downtown Wellington (source: GNS Science).

Ground shaking intensity (MM scale)	Return period (years)
V	2
VI	10
VII	50

VIII	150
IX	500
X	1000

3.1.4 Growth Statement

There is no evidence to suggest that the return periods of these events will increase or decrease over time, but the Wellington region is in the return period window for a magnitude 6.0-6.9 earthquake somewhere in the region and a penultimate faulting event on the Wellington Fault.

Community vulnerability is increasing over time as the population and density continues to grow, especially from inner city apartments and suburban in-fill development. The potential consequences from earthquake hazards are increasing as more development occurs in the region, and as reliance grows on built and technological infrastructure. Potential consequences are also increased where development takes place on or close to active faults, on areas of soft sediments or near steep/excavated slopes.

3.1.5 Urgency Statement

Considerable time has passed since the last movement on the Wellington fault (350-500 yrs) so this event has an element of urgency, because the fault rupture return period is 500-770 years. There is thought to be a 10% chance that this could occur in the next 50 years.

3.1.6 Consequences

Human

- Deaths greater than 500 possible during daytime event. Also a general increase in other mortality e.g. heart attacks, people in medical care.
- Injuries. Over 2000 people needing immediate attention, another 3000 injured and needing some medical attention. Dust asphyxiation issues.
- Possibly 1000 people trapped in collapsed buildings and people needing rescue from rail and road accidents.
- Traumatic stress

Economic

- Economy distorted, possible short-term recession
- Reluctance to invest in Wellington region and NZ
- Spike in insurance costs
- Boom in reconstruction industry
- Drop in the value of the NZ dollar
- Business continuity seriously affected.
- Repair costs for residential homes up to $4 Billion.
- 28% of all businesses in Wellington city extensively damaged. Many businesses lost.

Social

- Loss of family incomes
- Psychological distress and mental health issues arise
- Many people unable to inhabit their homes therefore temporary accommodation needed
- Public health concerns – lack of water, spread of disease. (especially if during winter or bad weather)
- Family and community groups disrupted.
- Schools unable to operate.
- Commuters can't get home.
- Families separated

Infrastructure

- Loss of water supply, electricity and gas possible.
- Some major transportation routes likely to be impassable.
- Phone and cell phone links could be cut.
- Hospitals working at reduced capacity.
- Emergency services stretched beyond capability. Emergency facilities may be damaged.
- Up to 900 domestic homes destroyed following maximum event. 350 of those by post event fires.

Geographic

- Fault rupture, scarp created
- Landslides
- Uplift or subsidence (e.g Hutt Valley 1-2m subsidence on western side)

3.1.7 Seriousness Statement

This hazard has significant consequences to people and property. Even though there is continual work being done on the earthquake hazard in the Region, it is important to recognise earthquakes as one of our most serious hazards and risks.

3.1.8 Current Management Mechanisms

- Training and exercises
- EQC residential insurance
- Wellington and Wairarapa Lifelines Group projects and ongoing work.
- Preparedness education
- District land use plans
- Geonet – earthquake monitoring and detection networks
- Building codes and standards
- Building on Faultlines – MFE guidelines and PCE report
- Research
- High risk buildings identified in many areas
- Innovations in earthquake engineering
- Emergency Management organisations and personnel

3.1.9 Possible Future Management Mechanisms

- Recovery strategic planning and management planning
- Subsidies to Lifelines for mitigation activities
- Stricter building codes and reassessment of land use plans.
- Preparedness education
- Resourcing for emergency response – e.g. rescue, logistics
- Higher levels of business continuity planning
- Research
- Fault avoidance zones
- Develop building importance categories and registers
- Non-regulatory measures
- Create reserves
- Develop covenants
- Engineering solutions
- Relocation and/or development away from faultlines as per MfE guidelines. Development and subdivision controls.

3.1.10 Manageability Statement

There is a large amount of effort across agencies and industries to manage the earthquake hazard. There is an element of difficulty in mitigating and managing the larger scale events.

3.2 Tsunami

3.2.1 Hazard Context/Description

(a) Tsunami generation and propagation

A tsunami is a series of waves generated by the sudden displacement of a water surface. The three main generating mechanisms are submarine fault ruptures, landslides or volcanic activity. Most tsunami (around 90% depending on location) are caused by a submarine fault rupture that results in the vertical displacement of the sea bed. These events are most commonly associated with shallow focus (< 30 km deep) earthquakes greater than M 7.0. When a section of sea floor is displaced vertically up or down, it results in a comparable volume of water being elevated above the surrounding sea surface. As the water surface attempts to equalise, energy is transmitted through the water as a series of low amplitude (~ 1 m in open ocean) but extremely fast moving waves. They can have periods (time interval between peak to trough of the waves) of over an hour and move at speeds of 500-700 km/hr in the open ocean. It is important to recognise that it is not earthquakes that generate tsunami, but rather a vertical fault rupture of the seafloor, that also results in the ground shaking we recognise as an earthquake. The Wairarapa earthquake in 1855 produced a tsunami up to 10 m in Palliser Bay, caused by a large vertical uplift of the seafloor in Cook Strait.

The remaining 10% of tsunami are generated by landslides (submarine or terrestrial) and volcanic activity (island or submarine). Landslides alone are responsible for around 9% of tsunami recorded globally, but for a range of reasons, it is about double this for New Zealand. Most commonly, the landslides are submarine in origin, often triggered by earthquake activity, but they may also be caused by rock fall or landslips into water. In 1988 a large rock fall in Deep Cove, Doubtful Sound lifted a 40 tonne boat 4.0 m onto the wharf. A 1.0 m tsunami occurred in Tauranga Harbour in 1979 after torrential rain triggered a cliff collapse into the water. It is not uncommon for a tsunami generated in a fault rupture event to be enhanced by a submarine landslide triggered in the associated earthquake. It is thought that the 1855 Wairarapa earthquake was enhanced in this way by a landslide off a sidewall of the Cook Strait Canyon. In 1947 the Gisborne region experienced a tsunami with heights up to 10 m, caused by a combination of fault movement off the coast and an underwater landslide triggered by the earthquake. The tsunami generated from landslides are quite directional in their travel. Depending on the characteristics of the failure, the wave may impact some areas severely, whilst having minimal impact on coastlines closer to the source area.

Other large-scale disturbances of the sea surface that can generate tsunami are bolide (e.g. meteorite) impacts. However, these events are so rare and unpredictable that they are not able to be realistically incorporated into tsunami modelling studies.

Every tsunami has a unique wave length, height and directionality. The amplitude and direction a tsunami travels as it propagates away from the generation area depends on the type of fault movement, including any displacement and the submarine bathymetry. Tsunami are subject to reflection and refraction (bending) as they pass through water of varying depths and around land masses. Large structures, such as the Chatham Rise, can focus tsunami waves, whilst submarine trenches, such as the Hikurangi Trough off the northeast coast of New Zealand can act as conduits. Continental shelves can reflect much of the energy from distant source tsunami, reducing its impacts at the coast, but can have the opposite effect with locally-generated tsunami by trapping the wave energy and reflecting it back onto the coast, enhancing its effects. Small scale features like headlands and bays can concentrate or disperse waves locally. This complexity can make it difficult to predict tsunami movements in real time during an event.

As a tsunami approaches the coast, the nearshore bathymetry controls its movements. Local variations in bathymetry and coastal geometry mean that places a few kilometres apart can experience large differences in wave height. In some cases, waves can be trapped by the bathymetry to travel along the coast as edge waves. In semi-enclosed waters, such as Wellington Harbour, waves of a particular period may interact with the geometry and dimensions of the embayment to excite a resonance that may last for hours and that cause waves in some parts of the harbour to be two or three times the height of the incoming waves at the entrance. Waves of other periods may be damped down so that their heights inside the harbour are less than the height of the incoming waves at the entrance. In the 1960 tsunami event that was generated off the coast of Chile, waves with a 2.4 hr period caused a resonance in Wellington Harbour that slightly amplified the wave height at this frequency.

When a tsunami approaches the shore it slows down and steepens up to sometimes produce a breaking wave. More commonly though, it effects a very rapid onshore flow of water not dissimilar to a fast moving tide that causes salt water inundation, scouring and deposition of debris. In the process this can cause major damage to buildings and infrastructure, widespread coastal flooding and result in injuries and loss of life. A lot of damage is caused by debris entrained in the flow. There is usually more than one wave and it is common for the third or fourth wave to be the highest. There may initially be a withdrawal of water from the coast if the wave trough arrives first, but this is not always the case. If the crest arrives first there will be no such warning, only an extremely rapid increase in water level and onshore flow of water. Water levels can fluctuate for many days after the initial event, causing localised current flows and interfering with the normal oscillation of the tides.

The inundation levels from a tsunami depend on the nearshore bathymetry (deep/shallow), the beach type (sand/gravel), the topography of the hinterland (steep/gentle gradient) and localised water levels, in particular, the tidal stage. As a rough guide, the run-up from a tsunami is approximately equal to its wave height. On steep, narrow coastal strips, the run-up will be greater and could be expected to reach 1.5-2 times the wave height.

It has been suggested that reefs around the coast of the region, particularly the south coast, would dissipate a tsunami and provide a level of protection to coastal communities. However, this is not the case, reefs will not prevent a tsunami from coming onshore. It may help slow down the current velocities, but the water level will simply rise over the reef. This is because a tsunami is not like a simple swell wave. It has a very long periodicity and characteristics more similar to a tide. In the same way that the reef does not stop the tides, it will not stop a tsunami.

(b) Effects of Tsunami

Most tsunami from source to impact are non-breaking waves that resemble very rapidly changing tides as they inundate the land. While non-breaking waves are not as energetic as breaking waves, the currents induced around streets and buildings during successive inundations and withdrawals mean that at water depths of 2.0 m or more are destructive and life-threatening. Even water depths of 1.0 m can cause significant damage and may wash people off their feet. Some tsunami, particularly those of short period, such as may be generated by landslides and submarine slumping, can come ashore as breaking waves. These are generally more turbulent than non-breaking waves of equivalent height. However, because of the energy loss through turbulence, they may not penetrate as far inland as a non-breaking wave. A tsunami may reach further inland if it occurs on high tide.

An equal amount of damage may occur during a tsunami as the water drains back to sea. This backwash will follow paths of least resistance along low points in the local topography and may be laden with material caught up in the flow (e.g. sediment, boats, timber, building debris, glass, vehicles). The presence of debris can significantly increase the damage done by a tsunami. Analysis of fatalities and injuries from tsunami events overseas shows that as many as 75% of fatalities can be caused by floating debris. A number of fatalities also occur when people are knocked down and drowned in the backwash as it returns seaward. Experience from overseas shows that wooden structures are most vulnerable to damage in a tsunami. Whilst reinforced concrete structures are strong enough to withstand severe tsunami flows.

Another serious health and safety risk during a tsunami comes from contaminants and hazardous substances that may become entrained in the flow. Ruptured fuel tanks from cars, boats or storage facilities can cause flammable liquids such as petrol or diesel to be spread over wide area and pose a major fire risk. Industrial areas may produce particularly toxic flood waters from a variety of spilled liquid and powdered hazardous substances, chemicals, paints or cleaning products. Similarly, a major health risk may ensue if raw sewerage becomes entrained in the flow. There is a need to identify these and other hazards in areas subject to tsunami inundation.

Tsunami can be a major secondary hazard associated with a large earthquake that may already have caused serious infrastructural damage, subsidence and liquefaction in low lying coastal areas. In these situations, a tsunami will have a greater ability to cause damage to already weakened structures or inflict fatalities to injured people, especially from increased amounts of debris due to the earthquake.

(c) Tsunami risk in the Wellington Region

With over 500 km of coastline, the Wellington region is exposed to tsunami from a range of sources. There are three main categories of tsunami to consider when preparing tsunami risk management strategies and evacuation warning alerts, based on travel time from generation source to the coast:

- Distant source tsunami (> 3 hrs travel time)
- Regional source tsunami (1 – 3 hrs travel time)
- Local source tsunami (< 1 hr travel time)

The Wellington region is at risk from tsunami generated from both distant (far-field) and local sources (near-field). Regionally generated tsunami are not considered to pose a threat. The level of risk around the region is not equal, rather it varies depending on exposure levels to local and distant sources. The Kapiti Coast is considered to have the lowest risk; Wellington a moderate risk and the Wairarapa coast (east and south) the highest risk. In general, the risk increases from low to high in an anticlockwise direction around the coast from Otaki to Castlepoint. Compared to the rest of New Zealand, the Wairarapa coast has one of the highest tsunami risks in New Zealand, In contrast, the Kapiti Coast has one of the lowest risks. Table 3.2.1 shows the mean wave heights for both local and distant source tsunami at 100, 500 and 2500 return periods for generalised areas around the region.

Table 3.2.1(a)(b). Generalised mean tsunami wave heights and return periods around the region expressed as a mean estimate in metres above sea level (*m asl*) for local source (a) and distant source (b) tsunami. Higher or lower water elevations may occur locally. (data source: GNS)

3.2.1a

Local Source Tsunami	**100 yr**	**500 yr** *crest – trough wave height (m asl)*	**2500 yr**
Kapiti/Porirua	0.9	2.7	5.5
Wellington (incl. south coast)	1.6	4.5	9.9
Wairarapa (incl. S & E coast)	2-4	4-6	8-10

3.2.1b

Distant Source Tsunami	**100 yr**	**500 yr** *crest – trough wave height (m asl)*	**2500 yr**
Kapiti/Porirua	0.5	1.0	1.5
Wellington (incl. south coast)	1.1	2.5	4.2
Wairarapa (incl. S & E coast)	< 2	2-4	6-8

Since 1848, a time span of 159 years, there have been four significant events that have impacted the Wellington region producing water level fluctuations of over 1.0 m. A further four events produced measurable fluctuations in the order of 0.15-0.35 m. Of these, six were distant source and two were local source.

The most significant distant source tsunami occurred on 22 May 1960 and was generated from one of the largest earthquakes in recorded history (M 9.2-9.4) off the coast of Chile. It produced a wave approximately 1.0 m high around Wellington and there were reports of a 1.5 m high wave at Ngawi. However, there were no reports of serious damage anywhere in the region. Part of the reason for this is because it arrived at low tide. Had this occurred at high tide, the consequences would have been more severe. Earthquakes off the coast of Chile present the largest far-field tsunami risk for the Central New Zealand region.

Whilst there are more tsunami from distant sources, they pose a lesser risk for two reasons. First, the warning times for distant tsunami, that can be up to 12 hours, provide ample time for people to evacuate the coast. Secondly, tsunami waves loose energy over time as they travel from the source area, reducing their impacts on distant shores. For example, the Solomon Island tsunami that occurred in April 2007, was generated from a large magnitude 8.1 earthquake that produced a maximum wave of 0.20 m around the Wellington coast.

The greatest risk from tsunami is from local source or near-field events. In these events the warning time is less than one hour. There are three potential sources of near-field tsunami for the region:

- Hikurangi Subduction Margin of Pacific/Australia Plate boundary off southeast coast
- Local faults in Cook Strait.
- Submarine landslides off Cook Strait Canyon.

By far the most significant tsunami since European settlement was generated by the Wairarapa earthquake on 23 January 1855. Water levels fluctuated from 1.2 m below low tide to over 3.0 m above mean high water springs. There were reports of 2-3.5 m breaking waves at Wellington Harbour heads and 4-5 m waves at Cape Palliser. There is one historical account of some wool sheds being destroyed in Palliser Bay that were situated approximately 9.0 m above sea level, providing an indication of the run-up limit. The Wairarapa earthquake was the largest earthquake in recorded European New Zealand history. With an estimated magnitude of 8.2, this earthquake is known in geological terms as the penultimate faulting event and provides an indication of the maximum sized earthquake that this fault can generate. In fact, an earthquake of this magnitude is at the upper limit of what could reasonably be expected to occur on any local fault.

The tsunami that was generated in the Wairarapa earthquake provides a good indication of the maximum sized tsunami that could be generated by submarine fault ruptures in the area. It is thought that this tsunami was enhanced by a submarine landslide off the Cook Strait Canyon, thereby adding to the size of the waves generated purely by seismic activity. It is thought that the Wairarapa fault is the only fault in Cook Strait that poses a significant destructive tsunami risk. The size of a tsunami is controlled largely by the amount of vertical displacement on a fault during rupture. All the other faults in Cook Strait are characterised by more by strike-slip or horizontal movement. This means that significant vertical displacement of the seafloor is unlikely to occur on these faults. The likelihood of these faults generating a tsunami over 2.0 m in height is considered low. The recurrence interval on the Wairarapa Fault is in the order of 1600-1900 years. Thus, the likelihood of this fault producing another maximum displacement in the near future is low.

The only exception to this is if a magnitude 7.0+ earthquake from one of the faults in Cook Strait triggered a submarine landslide. These have the potential to produce vary large waves and almost certainly contributed to the 1855 event. The science in this area is undeveloped and estimates of the magnitude or frequency of this type of event would be speculative, but the 1855 event provides a good indication of the size of any tsunami that may be generated from this source in the future. It is also possible that the 1855 earthquake actually reduced the risk from this source by dislodging unstable material in the Cook Strait area. Thus, landslides are unlikely to be a separate and large additional contributor to the tsunami hazard over that which already exists.

As discussed in section 3.1 on earthquakes, the presence of a subduction interface beneath the Wellington originating from the Hikurangi margin region is well established, but its risk potential is poorly understood. It is also unknown how much strain the subduction margin is able to accommodate and to what degree the plates are locked. Importantly for tsunami modelling, it is not known to what degree the plates are seismically coupled and thus the degree and type of rupture and rebound that may occur in a fault rupture event. It is known that the plates are moving at around ~ 28 mm/yr and that about half of this is resulting in deformation of the upper crust. However, about 15 mm/yr of this movement is unaccounted for and may be building up as strain on the fault. Modelling indicates that a rupture event could occur along 60 km of the interface, producing 8-15 m of displacement in a M 7.9-8.4 earthquake, with the best estimate being M8.2. The estimate of the recurrence interval for an event of this magnitude is in the order of 2000 years. Thus, there is potential for a very large tsunami to be generated if this fault ruptured.

3.2.2 Scenarios

Maximum probable event

Locally generated tsunami occurring at high tide, at night with wave heights in the order of 10 m and run-up elevations of between 10 to 20 m or up to 500 m inland from either:

(i) a rupture of the Hikurangi subduction margin;

(ii) a large submarine landslide off the Cook Strait Canyon;

(iii)a large fault rupture event resulting in vertical displacement of ~ 5 m on the Wairarapa or Wellington Fault

Event affects the whole region and may occur in addition to earthquake damage. Area most affected depends on the generation source. A rupture of the subduction margin might be expected to most severely affect the east and southeast Wairarapa coast. The effects of a large submarine landslide may will be more localised and will depend on the location of the slide, but Palliser Bay and Wellington south coast could be severely affected. A large fault rupture event in Cook Strait would affect the whole region, in particular the south Wairarapa coast, Palliser Bay, Wellington Harbour and south coast. Water could possibly flood the Rongotai-Kilbirnie isthmus. Significant seiching in the Wellington harbour and Lake Ferry to heights of 2 m above sea level. A bore may travel up the Hutt River. Reflection and refraction of waves along the Porirua and Kapiti coasts. Depending on the wave frequencies, waves may become trapped in Wellington Harbour or between Kapiti Island and the Kapiti Coast.

The largest risk would be to human life from injuries sustained by floating debris or drowning in the flow. Depending on the time of day and the day of week, there may be as many as 5000 injuries and 2000 fatalities. Two of the worst times would be a summer weekend when there are many visitors at the coast or at night when residents of coastal communities, that are mostly composed of low rise buildings, are home. Coastal infrastructure and buildings would be damaged, beaches may be heavily scoured and dunes eroded. Debris would be deposited across a wide area with associated issues from salt water damage. Further issues may result from hazardous substances entrained in the flow. Fires may result if fuel tanks or storage facilities are damaged and leaking. Costs may run up to $5 billion for an event of this magnitude. Forecast modelling indicates a 2500 yr return period.

Mid-range event

Local source tsunami, wave height 3-4 m, with limited or no warning arriving at high tide on a summer weekend. Highest risk areas are coastal communities of the east and south Wairarapa Coast (e.g. Mataikona, Castlepoint, Riversdale and Ngawi) and the Wellington south coast and Harbour area. Fatalities could number up to 100 and injuries in the 100's. Possible scouring and damage to coastal structures and light-moderate damage to wooden houses near the coast. Salt water damage around coastal land and possible bore up Hutt River could cause further flooding around low lying areas in Lower Hutt. Damages may run up to $1 billion. Forecast modelling indicates a 250 yr return period.

3.2.3 Likelihood

It is unlikely that the region would experience major impacts from a tsunami less than a 1:100 year event, even if it occurred on high tide. A 1:100 year tsunami will cause damage to structures around the coast, but would be unlikely to cause major structural damage. Based on the historical record, a 2.2 m tsunami may be considered a 1:100 year event for the Wellington area and a 5.3 m wave may be considered a 1:500 year event. Run-up elevations around the coast may be in the order of 3.0-4.4 m for a 100 yr event and 8-10 m for a 500 yr event.

Seventy percent of the 1:100 year events and 88% of the 1:500 year events can be expected to be generated locally, and have travel times of less than 1 hour. This includes tsunami generated on the Hikurangi Subduction Margin. A very large tsunami event (> 1:500 yr) has a low probability recurrence coupled with a high risk of severe impact. A moderate tsunami (1:100) as a medium probability of recurrence with a low-medium risk of severe impact.

A major review of the tsunami risk hazard in New Zealand was conducted 2005. The results of some probabilistic and disaster and risk modelling conducted for four sites in this region are presented in Table 3.2.2. The modelling takes into account tsunami from all sources (local and distant) and by default also includes the risk from submarine landslides. The results provide an indication of the wave height above mean sea level, the probable return periods and estimates of damages and casualties. The estimates are median values from the 50% probability percentile. Thus in reality, events may be smaller or larger than these estimates. No modelling was done for the Wairarapa, but estimates for this region will be similar to those for Wellington. The tables also indicate probable tsunami source areas by percentage. The subduction zone features predominantly in all these scenarios.

Table 3.2.2(a-d). Probabilistic tsunami modelling for four sites around the Wellington region showing wave heights above sea level, probable recurrence intervals and estimated damages and casualties. A breakdown of the probable tsunami source area is also included.

a

Wellington City	**50yr**	**100yr**	**200yr**	**500yr**	**1000yr**	**2500yr**
Height (m asl)	1.3	2.2	3.5	5.3	7.4	10.3
Cost ($ M)	17	350	1200	2500	3600	5300
Deaths	0	1	26	160	650	2300
Injuries	7	68	320	1100	2400	4800

Source Area	**2.2 m (100 yr)**	**5.3 m (500 yr)**
Subduction Zone	41%	69%
South America	30%	12%
Local Faults	29%	19%

b

Lower Hutt	**50yr**	**100yr**	**200yr**	**500yr**	**1000yr**	**2500yr**
Height (m)	1.0	1.6	2.4	3.6	5.1	7.2
Cost ($ M)	0	7	43	200	540	940
Deaths	0	0	0	2	13	54
Injuries	3	28	140	470	1200	2600

Source Area	**1.6 m (100 yr)**	**3.6 m (500 yr)**
Subduction Zone	41%	68%
Local Faults	28%	20%
South America	31%	12%

c

Porirua City	**50yr**	**100yr**	**200yr**	**500yr**	**1000yr**	**2500yr**
Height (m)	0.6	1.0	1.7	2.9	4.0	5.5
Cost ($ M)	0	0	36	230	410	670
Deaths	0	0	0	5	27	81
Injuries	0	3	24	100	230	450

Source Area	1.0 m (100 yr)	2.9 m (500 yr)
Subduction Zone	68%	73%
Local Faults	20%	26%
South America	11%	1%

d

Kapiti Coast	50yr	100yr	200yr	500yr	1000yr	2500yr
Height (m)	0.7	1.1	1.7	2.8	3.9	5.3
Cost ($ M)	0	0	25	190	430	780
Deaths	0	0	0	6	35	130
Injuries	0	8	71	250	500	1000

Source Area	1.1 m (100 yr)	2.8 m (500 yr)
Subduction Zone	61%	60%
Local Faults	22%	37%
South America	16%	3%

3.2.4 Growth Statement

There are no indications that the frequency of hazard occurrence is likely to increase. However, with the increasing popularity of coastal areas as places to live and recreate, the risk has been increasing over time. It is highly likely that this trend will continue in the medium term. Sea level rise associated with climate change may also increase the consequences of tsunami as the elevation between development and mean sea level decreases.

3.2.5 Urgency Statement

Few significant tsunami have affected New Zealand in the last 50 years. Nevertheless, a moderate sized tsunami is likely to occur somewhere in the region within the lifetime of an individual, lending the hazard an element of urgency.

The greatest risk is from locally generated tsunami. It is recommended that immediately after a very large earthquake, people move away from the coast. The warning time for these tsunami is very short – less than one hour and it could be a matter of minutes before the wave comes on shore. Evacuation to the upper stories level may be sufficient for all but the largest tsunami. The risk from large tsunami is faced by everyone who lives or recreates in coastal areas. Over the course of year, the risk is higher to people who live at the coast, compared to those who visit for short periods of time.

3.2.6 Consequences

Human

- Deaths. May number in the hundreds for locally generated events.
- Injuries (amputations, blunt trauma injuries from debris, crush injuries). May number in the 1000's for local events.
- Possible health effects from raw sewerage or hazardous substances.
- Emotional/psychological distress.
- Effects vary depending on time of year (esp. tourist/holiday locations) and time of day (esp. coastal residential dwellings and workplaces).

Economic

- Loss of family and business incomes.
- Building and infrastructure reconstruction.
- Loss of earnings from land made unusable by inundation.
- Loss of business confidence in coastal areas.
- Significant loss of ability to function in maritime industries (e.g. fishing, maritime transport), or those reliant on maritime transport (e.g. fuel delivery, importers/exporters).

Social

- Influx of media and researchers.
- Confusion, panic or distrust during warning phase (if warning existed).
- Family group disruption.
- Community group disruption.
- Short term loss of community facilities.
- People unable to inhabit damaged dwellings. Short and medium term alternate accommodation will be required.
- A number of schools and facilities for the elderly uninhabitable.

Infrastructure

- Destruction of coastal homes and businesses (including port facilities). This number could be thousands of residential properties.
- Coastal road access disruption and damage, undermining or scouring.
- Coastal infrastructure and utilities damaged/destroyed, especially from salt water inundation. Stormwater drains/sewer pipes may become overloaded.
- Possible fires from fuel leaks.

Geographic

- Saltwater inundation causing short term loss of vegetation and reduced land productivity.
- Longer term possible opportunity for species diversity in new habitats created.
- Erosion and debris redeposits may alter current coastal landscapes. This may affect water courses or drainage.

- Dunes may be severely scoured.

3.2.7 Seriousness Statement

The tsunami hazard has the potential to cause large scale loss of life and destruction. This is due to the nature of the hazard, but also due to the high concentration of people and assets in areas that could be affected.

3.2.8 Current Management Mechanisms

- Education for coastal communities
- Signage (MDC, SWDC only)
- Warning systems – PTWC, local warning arrangements
- Wairarapa Coastal Strategy – coastal hazard zone

3.2.9 Possible Future Management Mechanisms

- RPS objectives and policies, District plan rules (development control rules, set backs, tsunami hazard zones)
- Building act/building code
- NZ Coastal policy statement policies
- LTCCP objectives
- Provide incentives (e.g. waive fees, reduced rates)
- Research into run up effects and silt debris
- Contingency plans, evacuation plans
- Signage
- Education
- Warnings
- Identify vertical shelters for evacuation
- Inventory high risk areas and vulnerable facilities
- Recovery and replacement planning
- protection measures (barriers, plantations, tsunami resistant building design, lower floors for non-essential use, raised structures, retrofitting)
- Tsunami Loss Scenario studies
- Relocation of essential facilities

3.2.10 Manageability Statement

Tsunami events cannot be modified. The available responses are limited to avoiding tsunami prone areas, adopting engineering measures to reduce damage, and evacuation planning. Due to the small warning time and large impact of a locally generated tsunami the manageability for this event relies heavily on pre-event recovery preparation and education programmes. There is a need to have greater consideration of tsunami hazard when planning new developments in coastal areas, rather than relying solely on evacuation plans. Due to uncertainty in defining tsunami hazard zones and the long return periods for damaging events it is difficult for TA’s to include restrictions on development due to the tsunami hazard. A region wide study into potential tsunami impacts and inundation areas is a high research priority.

3.3 Volcanic

3.3.1 Hazard Context/Description

Whilst there are no volcanoes in the Wellington region, there is a residual risk from related volcanic activity. The biggest issue for the Wellington region is ash fall from volcanic eruptions in the central North Island. An eruption of Mt Taranaki, Mt Ruapehu or Mt Ngauruhoe could result in ash fall over the region causing damage and disruption. Ash fall is highly disruptive and requires a huge resource intensive clean up operation that is costly in terms of time, money and people. There will be logistical issues associated with dumping ash, that currently requires addressing. The Wellington civil defence group may need to support northern regions in the event of a major volcanic eruption.

The Wellington region has not been directly affected by ash fall in recent years. Ash from the 1995 and 1996 Mt Ruapehu eruptions was deposited over East Cape, Hawke's Bay and the Bay of Plenty by southerly and westerly winds. Given the lateral extent of these ash falls it is thought that the Wellington region would have received around ~1 mm ash fall if winds been northwest at the time of eruption. Although Wellington airport was not closed, flights between Wellington and other North Island towns were severely disrupted during these eruptions.

In a volcanic eruption, fine material is ejected upwards in a column before settling out downwind as a ash fall deposit. Ash fall deposits are composed of various proportions of volcanic glass, crystal or rock particles depending on the composition of the magma.

The thickness and grain-size of an ash deposit generally decreases quickly with distance from the volcano. The distribution of ash will depend on the initial grain size of the ash, the type of eruption and the local wind conditions (speed, direction). Ash particles commonly have sharp broken edges, which makes them very abrasive. This abrasiveness is a function of the hardness and shape of the ash material.

Freshly fallen ash grains commonly have surface coatings of soluble chemical compounds such as acid salts. For this reason ash can be mildly corrosive and potentially electrically conductive. These soluble coatings are derived from the interactions in an eruption column between ash particles and aerosols, which may be composed of sulphuric and hydrochloric acid droplets with absorbed halide salts. This process is most active close to a volcano (i.e. <50 km). When ash with these compounds settles on wet ground or in waterways the soluble components may dissolve and be released as leachates. This can result in changes to local water chemistry, reducing water quality and affect potable water supplies.

For ash fall to affect the region, a volcanic eruption needs to coincide with a strong northwest upper air flow. The highest risk comes from Mt Taranaki. Ruapehu and Ngauruhoe both pose a lower risk. This is because there is a higher likelihood of coincident norwesterlies during an eruption of Mt Taranaki, rather than the lower frequency north-northeast winds required to deposit ash from the central volcanic plateau.

3.3.2 Likelihood

Calculating return periods for ash fall in the region is difficult due to variations in source location, eruption size and wind direction. Ash falls are present in the geological record, particularly the northern Wairarapa, at intermittent time intervals over the past 25 000 years. Return periods for the Wairarapa are estimated at 1300-1600 years for a 1-5 mm ash fall from Mt Taranaki, and greater than 2000 years for a 1-2 mm ash fall from Mt Ruapehu or Mt Ngauruhoe. These estimates are based on the prevailing wind direction being northwesterly rather than northerly. Return periods for Wellington are not known, but are likely to be lower.

Large accumulations of ash (up to 30 mm in Wairarapa) could be expected from a prolonged eruption of Taupo or from the Okataina volcanic field in the Bay of Plenty but the recurrence interval for these events is >10,000 years.

3.3.3 Growth Statement

There is no evidence to suggest that there will be an increase in the frequency of volcanic events. There may be an increase in the strength and prevalence of the northwest airflow necessary to bring ash to the Wellington region from climate change over the next 100 years.

It is likely that a similar level of vulnerability to volcanic hazards will be maintained in this region due to their infrequent occurrence.

3.3.4 Urgency Statement

Although there is low recurrence interval for this event, it is important that the impacts of ash fall over the region are considered and prepared for. This is because even a small amount of ash can have quite serious effects.

3.3.5 Consequences

Human

- Increased asthma, bronchial illnesses and silicosis type illnesses.
- Ash acts as an irritant to lungs and eyes., especially if it contains acid salts.

Economic

- Possible minor damage to vehicles, houses, and equipment caused by fine abrasive ash.
- Airports will close due to potential damage to aircraft – flights coming from affected areas will be disrupted. Delay in delivery of supplies that arrive by air.
- Damage to electrical equipment and sub-stations. Some ash falls are mildly electrically conductive if they contain acid salts.
- High cost of cleanup. Issues with dumping of ash.

Social

- Temporary movement of people from affected areas.
- Ash affects road visibility and traction for an extended period.

- Minor damage to houses will occur if fine ash enters buildings, soiling interiors, blocking air-conditioning filters.

Infrastructure

- Reduction in electricity use may be required.
- Possible contamination of small water supplies, particularly roof-fed tanks.
- Electricity may be cut; short-circuiting occurs at substations if ash is wet and therefore conductive. Low voltage systems more vulnerable than high. Wet ash may break power lines.
- Water supplies may be cut or limited due to failure of electrical supply to pumps.
- Possible contamination of water supplies by chemical leachates.
- High water-usage will result from ash clean-up operations.
- Roads may need to be cleared to reduce the dust nuisance and prevent stormwater systems becoming blocked.
- Sewerage systems may be blocked by ash, or disrupted by loss of electrical supplies.

Geographic

- Possible crop damage.
- Possible enrichment of rural pastures.
- Some livestock may be affected; most will not be unduly stressed, but many suffer from lack of feed, wear on teeth, and possible contamination of water supplies.

3.3.6 Seriousness Statement

A small amount of volcanic ash fall can cause disruption to lifelines such as electricity, water, waste water, telecommunications and road networks. The major consequence of this disruption is economic losses.

3.3.7 Current Management Mechanisms

- Research
- National utility volcanic emergency plans

3.3.8 Possible Future Management Mechanisms

- Planning for temporary increase in people and businesses moving from affected areas.
- Identifying methods and locating equipment that can be used in a clean up.

3.3.9 Manageability Statement

There is little current effort into managing these hazards due to their low recurrence intervals. There is a need to find a suitable dumping area for the ash clean up spoils in the event and to identify and locate equipment required for a clean up.

3.4 Storm

3.4.1 Hazard Context/Description

Storms have a host of associated meterological phenomena and any given event may have some or all of these including, heavy rain, strong winds, lightning, hail and snow. In turn these may cause flooding, storm surge, coastal erosion and inundation, and landslips. In some situations the antecedant conditions will have a important bearing on the impacts of a storm. If the ground is already waterlogged at the end of a wet winter, there is increased risk of flooding and landslip during an event. A large storm has the potential to cause widespread damage across the region, initiating a local or region wide civil defence emergency.

The biggest storm in the last 100 years is thought to have occurred on February 2, 1936. However, few measurements exist from this event and the Wahine storm is commonly used a model 1:100 event. Around Wellington, the Wahine storm on April 9-10, 1968 brought sustained wind gusts of up to 150 kph, high seas and storm surges along the east and south coast.

Storms in the Wellington region generally come from three main sources:

(i) Southerly storms. Most commonly in winter, but can occur at any time of the year. Southerly storms bring with them, heavy rain, high sustained wind speeds and snow to higher elevations.

(ii) Northwest storms. These occur mainly in the spring months, in particular September and October, but a can also occur in August and November. There is also a smaller peak of activity in March. These times are related to the changing of the seasons on the spring and autumn equinoxes. Climate modelling indicates that the westerly airflow will strengthen over New Zealand in response to climate change pressures, indicating that the frequency of northwest storms may increase over the next 100 years. Northwest storms typically bring severe high winds to the region.

(iii) Ex-tropical cyclones. Cyclones form every year in the summer and early autumn months in equatorial regions due to warm sea surface temperatures and strong evaporation. Typically these systems decay before reaching New Zealand, but occasionally the sea surface and air temperatures remain warm enough to sustain them as they travel south. Typically, by the time they reach New Zealand they have weakened and are usually downgraded to ex-tropical cyclone status. On average they occur every 3 – 6 years. The most severe are events that approach from the southeast, as they track down the east coast of the North Island, such as cyclone Giselle (1968) (Wahine storm) or cyclone Bola (1988). These systems bring severe high winds (funnelled by Cook Strait), intense rainfall and high seas. Warmer sea surface temperatures due to climate change may allow the passage of more ex-tropical to the New Zealand over the next 100 years.

(a) Heavy Rain

A heavy rainfall event is defined as 100 mm over a 24 hour period, or a proportional amount falling over a shorter time period, e.g. 50 mm over 6-12 hrs. From April 8-10 , 1991 a severe rainstorm event caused flooding in the Wairarapa. Some of the heaviest falls occurred around Tinui, where 200 mm was recorded in one 24 hr period. In one event in the Wainuiomata Foothills in March 2005, 444 mm fell in 36 hours.

Heavy rainfall events have a range of effects that can lead to wide spread damage including; localised surface flooding and ponding due to lack of drainage; storm water system backup; river flooding and; landslides. Rainfall can be intensified due to convective or orographic influences. The classic mechanism for localised severe rainfall is a southerly front meeting a northwest front. Figure 3.4.1 shows the 100 year return period 24 hour rainfall for the region. The areas of greatest flood risk in the region are those catchments and floodplains that drain both west and east of the Tararua Range, where the highest rainfall occurs.

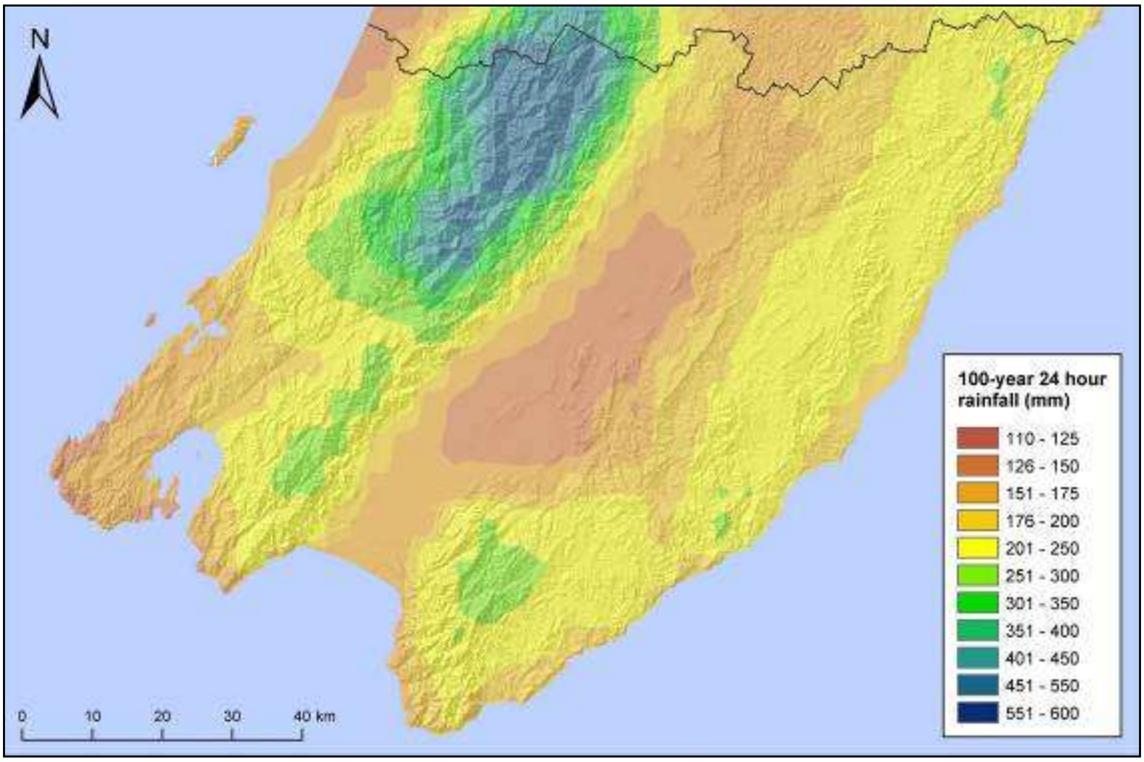

Figure 3.4.1. 100 year 24 hour rainfall probabilities for the Wellington region (source: NIWA).

(b) Severe Wind

Climate and topography make strong winds a frequent occurrence in the Wellington region. Westerly winds, turned south by the Tararua Range, are funnelled through the gap of Cook Strait to produce strong north or northwesterly winds in the western Wellington region. The Tararua Range also creates turbulent leewind waves in such conditions, causing gusty, high speed northwesterly winds in the Wairarapa. Southerly winds flow parallel to the main Wellington ranges and are not as strong or as characteristically gusty as the north westerly. However, southerlies have higher average sustained wind speeds.

Damaging winds blow on average about once a month, disrupting transport (particularly ferry crossings and plane landings), felling trees, power and telecommunication lines, and even lifting roofs. The windiest areas are generally the eastern Wairarapa coast (particularly Castlepoint & Tora) and the southern Wairarapa and Wellington coasts. Localised strong wind effects occur in areas such as Featherston, Mt Bruce, the summit area of the Rimutaka Road, Baring Head and Wellington Harbour entrance, including the airport. The Kapiti Coast can receive severe northwest gales in spring months, but is sheltered from the southerly by the Tararua range.

Wellington has 173 days per year of strong winds. Figure 3.4.2 shows the general variation in severe wind hazard across the region. The values are for wind at 10.0 m above ground level and do not take into account local topographic effects (hills, gorges and vegetation can create very localised wind effects). The return period for a severe wind gust (sustained over 3 sec) of 200 kph is roughly 140 yr. The return period may be lower around headlands, hills and ridge tops where winds are commonly accelerated by 30-40 %.

Climate change may increase the frequency of westerly component winds across the region, but the increase in severe wind occurrence is unknown. Severe wind events cannot be modified although localised wind effects, such as wind tunnelling along high-rise streets like Lambton Quay, can be mitigated to a degree by good design. The effects of severe wind can be mitigated by appropriate construction standards for buildings and infrastructure. Readiness is also a key component of mitigating severe wind, particularly as these events can generally be forecast.

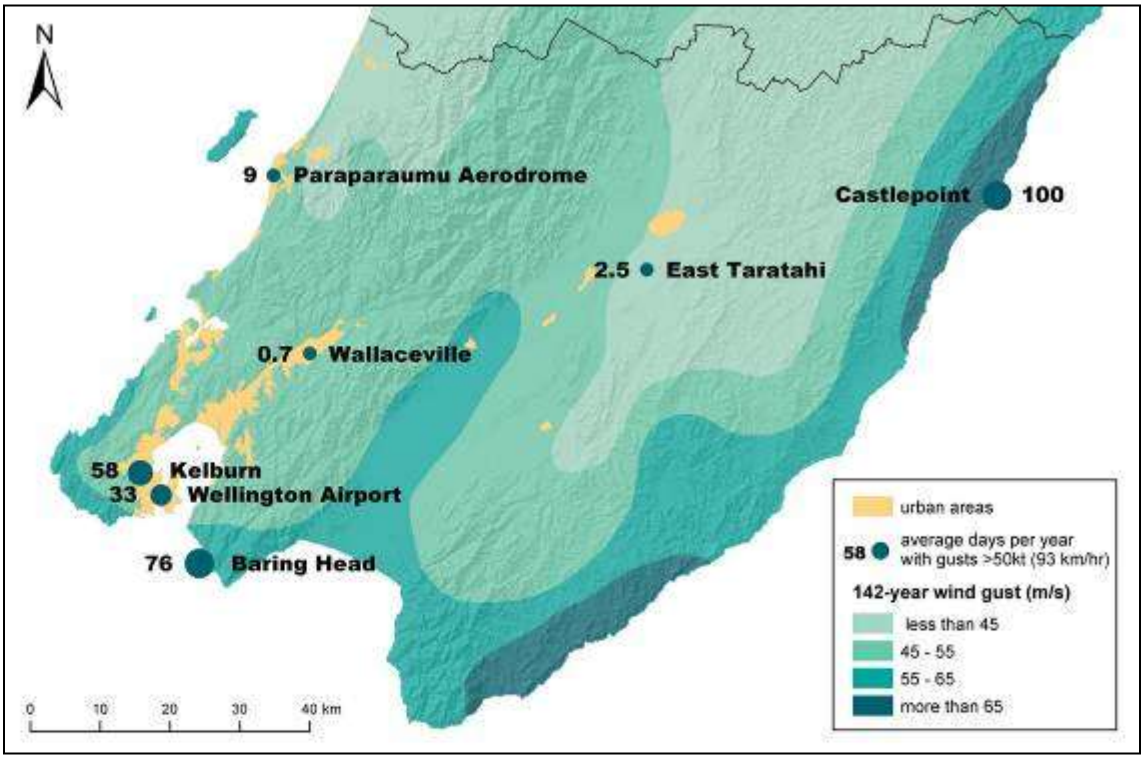

Figure 3.4.2. 142 year wind gust return periods for the Wellington region (source: NIWA).

(c) Lightning, Hail & Snow

Hail can occur in southerly storms, when a cold dry southerly front meets a warm moist northerly front, or from convection thunder cells (cumulonimbus) on warm summer days. Hail is considered severe when it is over 30 mm diameter (golf ball size) or when it causes widespread damage to crops, properties and vehicles. Local flooding due to ponding of hailstones in gutters or drains can be caused. Events are very localise and unlikely to affect the whole region in a single event. On average, there are between 1 to 5 hail days per year in the region. Climate change may increase the frequency or magnitude of hail storm events due to stronger convective heating in summer months.

Lightning occurs most frequently in the region during northwest storms, but also occurs when a cold dry southerly front meets a warm moist northerly front, or from cumulonimbus thunder cells. Lightning has very localised but severe effects. Individual risk is low and can be reduced to near zero if basic precautions are undertaken during a storm event. Certain areas in the region have a higher incidence of lightning strike over the course of a year. In particular, the Tararua ranges, north Wairarapa and Kapiti Coast. Power sub-stations, pylons and poles have slightly elevated risk and power blackouts can occur due to lightning strike in storm events. On average, there are between 0.15 and 0.7 lightning flashes per square kilometre every year in the region. Climate change may increase the frequency or magnitude of lightning strikes due to an increased prevalence of westerly winds and stronger convective heating in summer months, leading to thunder cell development.

Snowfalls occur in the region each year from southerly storms in winter and early spring. In particular, Upper Hutt, Hutt Valley, SH1 north of Paraparaumu and areas of high elevation > 500 m. Heavy snowfall is regarded as more than 25 cm falling in a 24 hr period or 10 cm in 6 hrs. Falls below 200m above sea level are infrequent but 1 per year maybe expected at between 200-500 m and 5 per year at 600-1000 m. More frequent falls occur at elevations above 1000 m. Climate change might be expected to reduce the number of snowfall days in the region, but there is the potential for an increase in the frequency of single severe southerly events that bring snow falls due to a change in the westerly winds that circulate around the Southern Ocean allowing more southerly outbreaks to cross the country.

(d) Storm Surge/Storm Tide

Storm surges have the capacity to cause significant damage to infrastructure and cause flooding in low lying coastal areas. This is especially true when they occur on top of a high tide, an event known as a ‘storm tide’. Storm surge is the short term elevation of the local sea level due to wave and meteorological conditions. Around the Wellington coast, storm surge can temporarily raise water levels to over 1.0 m above mean sea level.

Storm surge results from a combination of three factors; wind set-up, wave set-up and barometric lift. The amount of water level rise that each of these contributes is highly variable and depends on localised environmental conditions. Wind set-up occurs when strong winds force water onshore, causing an elevation of water levels at the shoreline. Wind set-up can account for up to half the water level rise in a storm surge.

When waves break at the shore, an upward slope of water occurs towards the beach face causing a localised rise above sea level. This is known as wave set-up and it is confined to the surf zone, that is, the area shoreward of initial wave breaking point. The degree of wave set-up depends on the height and period of the breaking waves, the nearshore bathymetry and beach slope. Thus, the wave set-up that occurs during a storm event will vary from site to site depending on the exposure of a shoreline to wave activity and the orientation and geomorphology of a beach. Wave set-up will be higher on exposed oceanic beaches, compared to more sheltered sites, and can account for up to one third of the storm surge elevation. The 10 yr return period for wave heights on Wellington south coast is 10.5 m and the 100 yr return period is 15.5 m. However, 10 m deep water wave swells occur every winter in Cook Strait.

Barometric lift occurs because, below air pressure of 1014 hPa, the sea surface rises *ca.* 1.0 cm for every 1.0 hPa drop in pressure. In a depression with air pressures of 970-980 at the centre, this equates to a localised elevation of 0.40-0.45 m.

In the Wellington region storm surge is most commonly associated with southerly storms and ex-tropical cyclones that bring with them strong winds, large waves and low air pressure. The Wahine storm (an ex-tropical cyclone) and the southerly storm of 1976 produced storm surges in exposed areas in the order of 0.80-1.0. m. The ex-tropical cyclone that affected the region in February 1936 is thought to have produced a storm surge in the order of ~ 1.20 m. These storms are all recognised as being 1:100 year events. A storm surge of this magnitude is capable of causing water to be elevated to around 2.0 m above mean sea level at high tide.

Table 3.4.1 presents the 10, 50 and 100 yr storm surge elevations for the Wellington coast. Elevations will be similar to the rest of the region, but will be slightly lower on the Kapiti Coast and in sheltered areas such as Wellington Harbour or Porirua Harbour. It can be seen that the 10 yr return storm surge is 0.40 m, 50 yr is 0.60 m and 100 yr is 1.20 m. The table also shows the elevations above mean sea level, mean high water springs and the highest astronomical tide. Mean high water springs is the average height of the high tides. The highest astronomical tide is an 18.6 year cycle during which time the tide levels are elevated above normal mean high water springs. When a storm surge occurs on top of a high tide or the highest astronomical tide it is known as a storm tide. It is important to remember that these events will continue to occur on top of ongoing eustatic sea level rise. Sea level is rising at rates of 1.78 mm/yr for Wellington and will have risen a further 16.5 cm by 2100 minimum. It is possible that sea level rise is accelerating and will be higher. Based on current measurements it may rise 30 cm by 2100.

Table 3.4.1. Summary storm surge elevations (m) for Wellington.

Return Period	Storm Surge	Height a msl	Height a mhws	Height a hat
10 yr	0.40	0.60	1.12	1.10
50 yr	0.60	0.80	1.32	1.50
100 yr	1.20	1.40	1.92	2.10

note: msl = mean sea level; *mhws* = mean high water springs; *hat* = highest astronomical tide

Places particularly susceptible to coastal flooding and overtopping include areas on the Kapiti Coast (Raumati South, Paekakariki), east Wairarapa coast (Castlepoint, Riversdale), Wellington south coast (Island Bay, Lyall Bay) and Wellington Harbour (Eastbourne, SH2).

3.4.2 Scenarios

Maximum Probable Event

100 yr ex-tropical cyclone event similar to or larger than the Wahine storm affecting entire region and initiating region wide civil defence emergency. Heavy rain across the region and severe localised falls in the Tararua's and western Wairarapa hill country. Rain fall leads to flooding in catchments of the Kapiti Coast (possible flash floods and debris flows in steep coastal catchments) and Wairarapa (bank overtopping and flood plain inundation). Surface flooding in low lying areas around Porirua and Wellington. Possible landslips in steep catchments such as the coastal escarpment at Paraparaumu/Paekakariki, western Wairarapa hills or hill suburbs in Hutt Valley or Eastbourne. Coastal erosion and inundation from storm tides at locations such as at Raumati Beach, Paekakariki, Eastbourne, Te Kopi and Castlepoint. Severe winds cause some structural damage to dwellings. Landslides cause disruption to road and rail networks on SH1 (Paekakariki) and SH2 (on Wellington-Hutt section) and slips in smaller roads around the region such as Akatarawa and Paekakariki Hill Road. Ferry sailings cancelled and airport closed. Emergency services access may be impaired. Possibility for major transportation incident (e.g. ferry, aircraft or train) and many small vehicle accidents (e.g. on Rimutaka Hill Road). Offshore wave heights up to 15 metres in Cook Strait. Telecommunications and electricity disrupted or intermittent in specific geographic areas. Localised storm water failure and possible sewerage overflow leading to contamination of waterways. Potential for some loss of life and many injuries. Costs of damage in the 100's of millions.

Mid-Range Event

50 year rainstorm with 6 hr rainfalls of 50 mm in localised places and 100 mm over 24 hrs across the region. Surface flooding and possible flash floods in steep catchments. Associated sustained gale force winds (> 60 kph), gusting storm force (> 120 kph), damaging many buildings and lifting roofs. Lightning strikes knock out some power supplies and localised severe hail storms damage crops, vehicles and some roofs. Significant emergency response required.

3.4.3 Likelihood

Rain Depths

- 100 yr return period 1-hour rain depths 40 mm
- 100 yr return period 24 hr rain depths 200 mm

Severe winds

- 142 yr return period 198 km/h
- 475 yr return period 216 km/h

Lightning and Hail

- Between 1-5 days of hail per year in region
- Between 0.15 and 0.7 lightning flashes per square km per year in region

Snowfall

- 1 per year at 200 - 600 m
- 5 per year at 600 - 1000 m

Storm Surge

- 10 yr return period 0.40 m above mean sea level (1.10 m on high tide)
- 50 yr return period 0.60 m above mean sea level (1.50 m on high tide)
- 100 yr return period 1.2 m above mean sea level (1.90 m on high tide)

Ex-tropical cyclones

- 1 every 3 – 6 years with various levels of impact

3.4.4 Growth Statement

General global climate change modelling suggests that meteorological hazards will increase over time, due mainly in part to increased sea surface and air temperatures. This produces conditions more conducive to the development of storms. Modelling by NIWA for the effects that this will have on the New Zealand region is inconclusive. New Zealand is insulated from extreme climate shifts from the Pacific Ocean and this may dampen down the potential increase in frequency of storm events. However, there are indications that the intensity of some of storms that we normally receive every year will increase. In effect, this will reduce the return periods for large storm events.

It is also possible that natural climate cycles, such as the El Niño Southern Oscillation (ENSO) and the Inter-decadal Pacific Oscillation (IPO), that have a measurable impact on local weather patterns will intensify with climate change. The ENSO results from cyclic warming and cooling of the Pacific Ocean sea surface. It is an important driver of natural climate variability influencing New Zealand’s rainfall patterns over a two to seven year time scale. The Southern Oscillation Index (SOI) is a measure of the air pressure difference between Tahiti and Darwin and indicates whether the oscillation is in a positive (La Niña) or negative (El Niño) phase. El Niño conditions generally result in more northwesterlies and greater summer rainfall in western areas. La Niña summers tend to produce more east/northeast flows with increased probability of tropical cyclones from the east. The IPO is a decadal-scale oscillation in the ocean-atmosphere system that modulates the frequency of El Niño and La Nino phases of ENSO. Evidence suggests we are entering a new negative phase of the IPO. This is likely to result in weaker westerly flows over the next 20 to 30 years, with more La Niña and less El Niño events. Effects for the region include increased probability of ex-tropical cyclones affecting the region from the east.

The risk to the community from storm events has been increasing over time as development continues to take place in flood plains, steep hill areas and coastal locations around the region. Infill housing on flood plains and hill suburbs adds to this problem.

3.4.5 Urgency Statement

There are many damaging meteorological events every year in New Zealand and within the region. These damage property, cause loss of lives and have major economic impact. Reducing the consequences of meteorological hazards is a high priority.

3.4.6 Consequences

Human

- Deaths possible due to persons being outdoors during the events, building damage, hypothermia, transportation accidents. (Historically number of deaths is low except when a transportation incident is caused).
- Many injured due to transportation accidents and building damage, extreme cold.

Economic

- Small business loss of ability to trade.
- Particular losses in agricultural sector.
- Loss of earnings due to transportation delays (e.g. maritime, rail, road transportation)

Social

- Building damage (e.g. loss of roofs) will mean increased demand for short term accommodation. Infill housing particularly vulnerable.
- Vulnerable sectors of community maybe more highly impacted (e.g. elderly, children, lower income earners)
- Temporary isolation of parts of the region due to access disruption.
- Water contamination possible
- Commuters unable to return home.

Infrastructure

- Destruction of electrical and electronic installations. Interruption of power and communications. (Trees a common cause)
- Blocked and damaged culverts. Stormwater networks overwhelmed
- Road and rails access disruption.
- Underground services damaged by landslides and erosion.

Geographic

- Agricultural land saturated and unusable.
- Destruction of plant life, crop damage. Trees uprooted.
- Debris dams formed
- Loss of coastal land

- Landslides forming new geographic structures and hence hazards.

3.4.7 Seriousness Statement

This hazard has the potential for significant impacts and destruction.

3.4.8 Current Management Mechanisms

- Cyclone tracking systems
- Building Act and Standards
- Warning systems and forecasts
- Education
- National Coastal Policy Statement
- Contingency and emergency response plans
- Protective structures for frost events
- Coastal Hazard Guidance note for local government
- KCDC Coastal Erosion Hazards Management Strategy
- Wairarapa Coastal Strategy

3.4.9 Possible Future Management Mechanisms

- Enhanced warnings and forecasts for quicker response, 24 hours and more localised information available.
- Utilities pre-planning away form coastal areas and to wind standards.
- Wind designed structures
- Protect the natural defences to coastal erosion e.g. dunes, beaches, cliffs, wetlands, coastal vegetation
- Soft structure defence work for coast erosion e.g. beach nourishment, coastal revegetation, drainage, runoff controls
- Hard structural defences for coastal hazards e.g. seawalls, building reinforcement, groynes, stopbanks, breakwaters, geotextiles.
- Manage land use to avoid areas of coastal hazards e.g planned retreat, restrictive zoning, design controls, setbacks, reserves, land swaps, transferable development rights.

3.4.10 Manageability Statement

Very good detection, monitoring and warning systems exist for these events. Public awareness is high and deaths and injuries can be minimised by ensuring people are removed from the worst effects. Events are most often of short duration, hours rather than days, but can be longer for major flooding events. More effort and time will be spent during recovery than during the immediate emergency response.

3.5 Flooding

3.5.1 Hazard Context/Description

Frequent heavy rainstorms, the steep gradients of many river catchments and human occupation of floodplains combine to make flooding the most frequently occurring natural hazard event in the Wellington region. Development on the floodplains of major rivers in the region requires that this hazard be carefully managed. Despite the degree of protection provided by river engineering works on many of the rivers in the region, there remains a residual risk in the event that stopbanks are overtopped or fail.

A flood occurs when an area of land, usually low-lying, is inundated with water. There are many different types of flooding events, each with its own cause and geographic characteristics. All these types of flooding events can happen in the Wellington region:

(i) Surface flooding or ponding due to impeded drainage. This commonly occurs in swampy or low lying areas particularly around estuaries and inlets. Can occur after a heavy rain storm due to blocked storm water drains. Antecedent conditions may exacerbate problems if the ground is waterlogged and the water table is high. Can occur around Porirua Harbour and Pauatahanui Inlet, Lake Wairarapa and localised areas around the region, such as interdune depressions on Kapiti Coast, Wellington City and Lower Hutt.

(ii) Coastal flooding from tsunami that can affect any part of the region or storm surge overtopping in places such as south Wellington coast, Wellington Harbour (Eastbourne, SH 2), Centennial Highway (SH 1) on Kapiti Coast, as discussed in tsunami and storm sections.

(iii) River flooding from bank overtopping onto flood plains. This is usually associated with prolonged heavy rainfall in catchment areas, but can also be due to snow melt. Peak flood flows can be heightened by vegetation clearance in the catchment, reducing the ability of the soils to hold water so that it is released more quickly into the river system. Floodwaters from these events frequently contain debris such as branches and rocks that can act as a battering rams and increase damages to infrastructure like bridges or houses. Sewerage can sometimes become entrained in the flood waters, providing an additional health risk. Significant deposits of silt, sand and gravel may cover large areas after floodwaters have receded, adding to the damages caused by the water. Particular risk areas in the region include the Otaki and Waikanae River flood plains, Lower Hutt and flood plains in the Wairarapa. Smaller watercourses have the potential to cause localised flooding in heavy rainfall events.

(iv) Flash flooding (often associated with debris flows) caused by intense heavy rainstorms in short steep catchments. A flood that rises and falls rapidly with little or no advance warning is called a flash flood. Can occur in Waikanae, Paekakariki, and locations along the southern and eastern Wairarapa coast. It commonly occurs in places backed by a steep coastal escarpment. The problem is worsened by vegetation clearance in the catchment area. This allows bare soils to be more easily eroded and increases runoff due to a reduction in the amount of water that can be held in the soils. Thus, peak flows are reached much more quickly.

3.5.2 Recent Major Flood Events

The region has been affected by a number of severe floods in the last ten years causing four deaths and tens of millions of dollars of damage - over $11 million cost to Greater Wellington flood protection works alone. Table 3.5.1 shows details of major floods to affect large parts of the region within the last ten years. The amount of damage caused by a flood varies from one river to another depending on the degree of flood protection, and the amount of development on the floodplain.

Table 3.5.1 Major floods in Wellington region in past 10 years.

Catchments (return period in years, where known)	Flood protection work damage estimates ($000s)		Comments
4 OCTOBER 1997			
Wainuiomata (5-15) Orongorongo (6) Hutt (3-10) Waikanae (3) Otaki (1) Porirua (1)	Hutt Otaki Waikanae	789.5 75 10	Northwesterly storm - 650mm over 48 hours recorded in the Tararua Range. Damage/erosion to Hutt River banks, part of Manor Park Golf Course eroded. Surface flooding in Hutt Valley and Wellington. Stormwater drain bursts in Ngauranga Gorge sending water and boulders down SH1 into traffic. One evacuation in the Akatarawa Valley. Two deaths (car aquaplaned into swollen Hutt River).
20/21 and 28 OCTOBER 1998			
20/21 October: Waikanae (28) Akatarawa (17) Waitohu (14) lower Hutt (12) Waipoua Ruamahanga 28 October: Akatarawa (75) lower Hutt (25) Otaki (10)	Total amounts: Hutt Otaki Waikanae Waitohu	 1375.5 442.2 156.1 25	20/21 October: Northwesterly storm - 620mm over 48 hours recorded in the Tararua Range, 100mm over 24 hours at Paraparaumu Airport. Civil Defence Emergency declared in Kapiti Coast. 13 homes evacuated in Waikanae, properties flooded. Properties and schools flooded in Otaki. Evacuations in Paekakariki/Paraparaumu due to water/sewerage problems. SH1 and rail inundated on Kapiti Coast. Rimutaka, Akatarawa and Paekakariki Hill Roads closed. Damage/erosion on Hutt River banks, part of Manor Park Golf Course eroded. 68 people evacuated from a school camp in Masterton after Waipoua River stopbank breach, extensive damage to camp ground. Roads closed in the Wairarapa. 28 October: Northwesterly storm on already saturated ground. Civil Defence Emergency again declared in Kapiti Coast. 40 people evacuated from Waikanae. SH1 closed north of Otaki after approaches to Waitohu Bridge washed out. One death (man swept away by the Waikanae River while checking the river bank on his property). Parts of Hutt Valley flooded. Roads, parks, golf courses inundated, properties flooded and homes evacuated. Parts of Wairarapa flooded and roads closed.
2 OCTOBER 2000			
Akatarawa (10) Hutt (6-10) Waitohu (7) Otaki (6) Waikanae (5) Mangaroa (5) Wainuiomata (3) Porirua (1) Ruamahanga	Hutt Otaki Waikanae Waitohu	245.4 186.9 97.3 25	Northwesterly storm - 850mm over 72 hours recorded in the Tararua Range. One house affected in the Hutt Valley. Ruamahanga River flooded large areas, homes isolated and roads closed.

Cont…		

8/9 OCTOBER 2000		
Ruamahanga Waiohine Waingawa Waipoua		Heavy rain in the Tararua Range - ~300mm in 24 hours. Roads and bridges damaged, stock losses.
10 JUNE 2003		
Wainuiomata (12)		Heavy rain in Wellington region, particularly Hutt Valley (123mm in 24 hours) and Wainuiomata (200mm in 24 hours). Roads and properties flooded, Wainuiomata River highest flow since 1977, sheep drowned and collapse of coast road.
3 OCTOBER 2003		
Whakatikei (60) Horokiri (~60?) Mangaroa (11) Waikanae (4-5) Hutt (4) Waiwhetu (4) Wainuiomata (3) Ruamahanga (7)		Heavy rain in the Tararua, Akatarawa and Rimutaka ranges. Most intense rain at Paekakariki where a Civil Defence Emergency was declared. Properties, roads and rail inundated by water, mud and debris from gullies behind the town. Rainfall over 6 hours in the hills behind Paekakariki was estimated to have a greater than 120 year return period.
11-19 FEBRUARY 2004		
Waiwhetu (50) Wainuiomata (30) Mangaroa (14) Porirua (6) Otaki (5) Waikanae (5) Hutt (4)	Hutt 75 Otaki 136 Waikanae 15 Wellington watercourses 210.7 Kapiti watercourses 4.5	Series of intense storms - worst storm on 15/16 February. Extensive flooding, landslides and damage to houses, farms and infrastructure in lower North Island. 41 homes evacuated and 15 commercial properties flooded in Waiwhetu. Local motor camp evacuated. 2 houses evacuated in Wainuiomata. Roads closed in Lower Hutt, Wainuiomata and Eastbourne. 10 families evacuated in Te Marua, Pinehaven and Akatarawa. 35 people stranded on Rimutaka Road. 2 families evacuated in rural Masterton.
18 AUGUST 2004		
Hutt Wainuiomata		Severe southerly storm. Flooding and many landslides in the lower Hutt Valley, Wainuiomata and Eastbourne and the Wairarapa. Postal worker drowned when trying to negotiate a flooded stream north of Bideford.
5/6 JANUARY 2005		
Waikanae (80) Akatarawa (80) Whakatikei (60) Otaki (40) Hutt (25) Mangaroa (12) Mangaone (10) Waiwhetu (5)	Hutt 591.5 Otaki 214.5 Waikanae 255.6 Kapiti watercourses 4.5 Pinehaven Stream 15	Northwesterly storm - 300mm over 12 hours in the Tararua Range. 23 properties inundated in Waikanae, 650 people evacuated from camp ground in Waikanae. SH1 and Main Trunk rail closed at McKay's Crossing. 10 properties affected in Hutt Valley, 3 homes evacuated in Pinehaven, 1 home evacuated in Akatarawa.
30/31 MARCH 2005		
Mataikona Wainuiomata Orongorongo Catchpool		Southeasterly storm - 444mm over 36 hours in Wainuiomata. Damage to farmland - silt covered paddocks, fences destroyed and stock lost. Large amounts of gravel mobilised in debris flows in the Orongorongo Valley - landslide dam created and several tramping huts damaged or destroyed. 15 adults and 5 children evacuated from homes in eastern Wairarapa.

3.5.3 Scenarios

Maximum Probable Event

500 yr flooding event on the Hutt River exceeding the design standard of the stop banks. Heavy intense rainfall from a stationary front bringing over 500 mm of rain over a 36-48 hour period to the Hutt River Catchment. Complete flooding of Hutt Valley floodplain affecting both upper and lower valley. Thousands of people evacuated and many require emergency accommodation, some maybe dislocated for months after the event. Several lives lost. Significant damage to bridges and roads, dwellings and buildings. Storm water systems blocked and overflow adding to the problem. Sewerage contaminates floodwaters in many parts. Water and power supply disrupted.

The same weather system will have caused flooding in the Otaki or Waikanae River valleys and high river flows with surface flooding in the Wairarapa. Surface flooding in Porirua and parts of Wellington city from storm water back up. Leads to a region wide civil defence emergency.

Mid-Range Event

100+ year flood event on Waikanae or Ruamahanga River floodplains. Significant surface flooding to many properties. River flooding due to damaged/overtopped protection works at a small number of sites. Wairarapa towns isolated and all floodways in operation. Significant stock losses and damage to crops. Damage to bridges and roads. Storm water and potable water systems damaged.

3.5.4 Likelihood

Annual exceedance probabilities exist for all rivers in the region. These are calculated by measuring the volume of water flowing in a river during a flood event and determining the probability of that size flow happening in any given year. Thus, 1:100 year flood volumes will differ from river to river. Table 3.5.2 shows the degree of protection in place along the Hutt, Waikanae and Otaki Rivers.

Table 3.5.2. Levels of protection planned for the Hutt, Waikanae and Otaki rivers.

Hutt River Floodplain Management Plan
Lower Valley
Major stopbanks: 1 in 440 year return period flood with additional stopbank capacity (freeboard) and associated bank-edge protection. Manor Park stopbank: 1 in 440 year return period flood. Belmont edge protection: 1 in 100 year return period flood.
Upper Valley
Major stopbanks: 1 in 1000 year return period flood with associated bank-edge protection of 1 in 440 year return period flood. Bridge Road edge protection: 1 in 100 year return period flood. Gemstone Drive stopbank and edge protection: 1 in 100 year return period flood. Totara Park stopbank: 1 in 440 year return period flood.

Waikanae River Floodplain Management Plan	
Stopbanks: 1 in 100 year return period flood. House raising to 1 in 100 year return period flood level (where viable, as an alternative to stopbanks).	
Otaki River Floodplain Management Plan	
Stopbanks: 1 in 100 year return period flood. House raising to 1 in 100 year return period flood level (where viable, as an alternative to stopbanks).	

3.5.5 Growth Statement

General global climate change modelling suggests that meteorological hazards will increase over time, due mainly in part to increased sea surface and air temperatures. This produces conditions more conducive to the development of rain storms. Modelling by NIWA for the effects that this will have on the New Zealand region is inconclusive. New Zealand is insulated from extreme climate shifts from the Pacific Ocean and this may dampen down the potential increase in frequency of storm events. However, there are indications that the intensity of some of storms that we normally receive every year will increase. This modelling also indicates that there will be an increase in the incidence and strength of the westerly airflow over the region. If this occurs, it is likely that there will be increase in rainfall on the Kapiti Coast and central Wellington in addition to an increased risk of heavy rainfall events across the region. It is also possible that natural climate cycles, such as the El Niño Southern Oscillation (ENSO) and the Inter-decadal Pacific Oscillation (IPO), that have a measurable impact on local weather patterns will intensify with climate change. Hence, there is the potential for the return periods for flood events to reduce over the next 100 years.

Land use change may also alter hydrological regimes which affect flood flows and intensity. While there have been few studies into the impact of land use change on flooding in the Wellington region, it is likely that human modification of catchments and floodplains has increased the flood hazard risk. Forest clearance in upper catchments reduces the ability of soils to hold water, thereby increasing the runoff during storm events. Expansion and intensification of urban catchment areas causing more rapid runoff and larger peak flood flows due to impermeable surfaces.

A combination of floodplain development, climate change and catchment modification means that the risk to many communities in the region from flood events has been increasing over time. As many as 70% of new subdivisions in the Wairarapa are at risk of flooding. In the Hutt Valley, despite the flood protection works, a residual flood risk still exists. Land at risk of residual flooding continues to de developed, with new subdivisions, in-fill housing and industrial/commercial estate.

3.5.6 Urgency Statement

The flood hazard has been managed in the Wellington region for many years and a number of rivers have specific flood management plans in place, effectively reducing the risk. Flooding causes ongoing wide spread damage in the region and continues to be the most costly natural hazard to manage, in terms of damages, insurance payouts and mitigation works. Considering the number of people that can be affected by flooding and the potential damage to infrastructure, agricultural land, business's and private dwellings, it is important that this hazard continues to managed.

3.5.7 Consequences

Human

- Deaths and injuries are likely from people being caught in flood waters
- Emotional/psychological distress

Economic

- Significant economic effects of damage to structural protection works, direct building and infrastructure damage, loss of income for businesses affected, loss of business confidence
- Significant stock and agricultural losses in rural areas

Social

- Public health concerns due to sewerage and lack of potable water
- Family group disruption
- Community group disruption
- Short term loss of community facilities
- Short and medium term alternate accommodation requirements
- A number of schools and facilities for the elderly uninhabitable
- Commuters stranded
- Domestic animals separated from homes and needing feeding/accommodation

Infrastructure

- Water supply interrupted and contaminated
- Waste water and storm water systems overwhelmed
- Electricity and telecommunications disrupted as facilities flooded
- Significant damage to road networks

Geographic

- Debris and landslides can change river courses
- Possible loss of production for flooded agriculture and horticulture areas
- Damage to wetlands, riverbank and river mouth ecosystems
- Erosion and realignment of river systems possible

3.5.8 Seriousness Statement

Flooding, whether small or large, has the potential to cause damage, loss of life and significant economic and community disruption.

3.5.9 Current Management Mechanisms

Intense and/or prolonged rainfall cannot be avoided. However, flood events can be modified by decreasing rainfall runoff rate (e.g. by planting trees in upper reaches of catchments) or by containing the flood (e.g. by constructing stopbanks).

Vulnerability to flooding can be reduced by avoiding high risk areas prone to repeated flooding, or by requiring minimum floor levels on floodplains. Response and recovery plans are also an important way to reduce the impacts of a flood event on the community. Some of the main mechanisms in place to manage the flood hazard risk are:

- Catchment management plans
- Stormwater asset management plans
- Watercourse agreements between landowners, Territorial Authorities and GW.
- Flood policies in city and district plans and the Regional Policy Statement
- Floodplain management plans (in general these aim to cover most of the following aspects):

  Structural protection
  Lifelines and habitable premises removed from the primary river corridor
  Overflow paths
  Monitoring of rainfall and river flows
  Education
  Signage
  Warning systems
  Contingency and response plans

(a) Flood protection

Greater Wellington's Flood Protection (Wellington/Hutt/Kapiti) and Operations (Wairarapa) departments provide flood protection for the major rivers in the region. This includes floodplain management planning and flood protection activities such as stopbank construction, waterway/asset management and gravel extraction.

Floodplain management plans have been prepared for the Hutt, Waikanae and Otaki rivers. These give a 40 year blueprint for managing and implementing programmes to gradually reduce the effects of flooding. The plans outline the level of protection that each community has decided is most appropriate and cost effective, and the measures that will be taken to achieve these standards. The level of protection designed for is defined by flood return period (e.g. 1 in 100 year return period flood).

Floodplain management plans outline both structural and non-structural methods for reducing the effect of floods. Structural methods include stopbanks and rock/vegetation protection. These methods are designed to keep the river in its channel, or river corridor, and away from populated areas and valuable community assets. Non-structural methods deal with the residual risk of flooding (risk left after structural flood protection works are in place) and land use planning controls. These methods involve improving community resilience to flooding and helping people avoid the flood hazard, and encouraging property owners to take responsibility for lessening the effects of floods.

Historical and existing flood protection structures mean that different areas of a river are protected to different levels. Some stopbanks along the Hutt River were built decades ago and may only provide protection against a 1 in 100 year return period flood, whilst the newest protection works have been developed to contain a 440 yr flood level. The floodplain management plans outline how and when these different areas will be brought up to the chosen level of protection using structural methods, and what other alternative methods will be used.

River schemes are in place for the Waiohine, Waingawa, Waipoua, and upper Ruamahanga rivers and the lower Wairarapa Valley (the Lower Wairarapa Valley Development Scheme incorporating Lake Wairarapa and the lower Ruamahanga River). These schemes include stopbank construction and annual programmes of groyne maintenance, planting, channel alignment and gravel extraction.

Table 3.5.3 outlines major structural works, including stopbank construction, river realignment and bank edge protection, undertaken by Greater Wellington on the Hutt, Waikanae, Otaki, Waiohine and Ruamahanga rivers, as well as the Lower Wairarapa Valley Development Scheme over the last ten years.

Table 3.5.3. Major structural works recently completed or in progress on rivers around the region

Hutt River	
Alicetown stopbank	Design completed 2005 (construction due for completion 2007)
Norfolk Street stopbank	Completed 2004 (some additional work ongoing)
Strand Park stopbank	Design completed (construction due for completion 2010)
Opahu pumping station	Design completed (construction due for completion 2006)
Ava Bridge stopbank	Design completed (construction due for completion 2006)
Whirinaki Crescent	Design completed (construction due for completion 2007)
Otaki River	
Chrystalls stopbank	Completed 2000
Chrystalls extended stopbank	Construction due for completion 2008
Rangiuru floodgates	Completed 2002
South Waitohu stopbank	Construction due for completion 2008
Mangapouri Stream Culverts	Three culverts completed 2003
Waikanae River	
Kauri-Puriri stopbank	Completed 1997
Kauri-Puriri Greenway road raising	Completed 1997
Kauri-Puriri removal of Riverside Lodge	Completed 1997
Kauri-Puriri Chillingworth stopbank	Completed 1997
Otaihanga road raising Stage 1	Completed 2000
Otaihanga road raising Stage 3	Completed 2004
Otaihanga house raising Toroa Rd	Completed 2000
Otaihanga house raising Makora Rd	6 of 15 houses proposed in Long Term Council Community Plan
Jim Cooke Park channel realignment	Currently underway

Lower Wairarapa Valley Development Scheme	
Tauherenikau stopbank upgrade	Completed 1995 and 2001
Papatahi stopbank	Completed 2003
Shifting Scaddens & Herricks stopbanks	Completed 2005
Sheltons & Guscotts repair	Completed 2005
Waiohine River	
Greytown stopbank construction	Completed 1998
Tui Glen & Fullers Bend upgrade	Completed 2004
Channel and protection works	Completed 2001
Wongs channel works	Completed 2001
Upper Ruamahunga River	
Te Whiti stopbank upgrade	Completed 2004
Rathkeale stopbank upgrade	Completed 2002

(b) Flood warning

Greater Wellington provides flood warnings to the region's urban and rural communities. Data is collected from a network of 48 automatic rainfall stations (42 Greater Wellington, 5 MetService and 1 NIWA) and 44 automatic river level monitoring stations (34 Greater Wellington, 9 NIWA, 1 joint Greater Wellington/NIWA). Most sites, located at strategic positions across the region, are telemetered and transmit real-time information via radio or cell phone to Greater Wellington.

After receiving a heavy rain warning from weather forecasters, Greater Wellington staff monitor the information transmitted from monitoring stations. Information collected every 15 minutes is compared to pre-set alarm levels. If rainfall and river levels reach the alarm point the system automatically warns staff.

Where possible, territorial authorities and landowners are given advance warning of the situation. Incoming data is updated at least every hour and flood predictions are adjusted accordingly.

MetService also gathers, analyses and disseminates weather information. MetService issues a Severe Weather Warning when >50mm of rain is expected in a widespread area within the next 6 hours or >100mm of rain is expected in a widespread area within the next 24 hours. A Severe Weather Watch is generated if >50mm of rain in 6 hours or >100mm of rain in 24 hours is expected to occur 24 to 72 hours into the future. These messages are disseminated to CDEM groups.

3.5.10 Possible Future Management Mechanisms

- Management plans for smaller water courses (not necessarily rivers)
- Enhanced structural protection (as defined in existing FMPs)
- Review of existing FMPs
- National policy statement on flood management being prepared by MfE
- Flood forecasting, for example:

NIWA meteorologists and hydrologists can now forecast floods caused by heavy rain with greater lead-times than has been possible in the past and is now implementing this research as an operational forecasting technique. This work is being done in collaboration with Regional Councils who supply their river flow data to NIWA. Forecasts up to 36 hrs ahead can be prepared daily for all major river catchments and then supplied to relevant flood managers and emergency management groups. These can be broadcast in summary form on the NIWA website or through other channels. The forecasts can be broadcast in terms of their predicted severity:

- moderate (smaller than the 5-year flood)
- severe (once every 5 to 20 years)
- extreme (bigger than the 20-year flood)

3.5.11 Manageability Statement

There is a moderate-high level of manageability for flood events. Structural protection works capable of withstanding floods with return periods between 50-440 years are in place on many floodplains in the region. During a flood event, evacuation procedures are in place to reduce casualties.

3.6 Landslide

3.6.1 Hazard Context/Description

The geology, tectonic setting and climate make the Wellington region particularly prone to landslides and there have been many events in the region over the years. The landslide hazard of the region results from a combination of the predisposed geomorphology, human modification of the environment and poor planning decisions coupled with poor engineering/maintenance of protections works. Landslides are second only to flooding in terms of the economic costs as a result of damages, insurance payouts and mitigation works required to control their effects.

Landslide is a term commonly used to refer to a range of slope failures that may more correctly be referred to as mass movement. Mass movement is a down-slope transfer of materials (including rock, earth, mud or debris) mobilised under the influence of gravity. These movements can be very slow creeping events that induce damage over a long period of time or they can be rapid events that happen in minutes to seconds. Mass movements include debris flows, subsidence and rock falls.

The susceptibility of an area to mass movement depends on the angle and aspect of the slope, the vegetation cover, the soil or rock characteristics and any modifications carried out on the slope (e.g. cuts, fills, earthworks). Whether a slope fails or not depends on a balance between the strength of the slope material and the driving or shear stress acting on the slope. Failure can occur when either the shear stress is increased, the strength is decreased or from a combination of the two. The main aspects of the two factors involved in slope failure are:

Increased Shear Stress

- Increase mass (rainfall or snow melt, colluvial deposition, building development, leaky water/sewer/storm water pipes)
- Vibration forces (earthquake shaking, heavy traffic)
- Increased slope angle (tectonics, toe erosion, colluvial deposition, slope cutting)

Decreased Material Strength

- Rainfall or snow melt (affect clay minerals, decreases frictional strength, erosion)
- Vegetation destruction (forest fires, avalanches, catchment clearance)
- Rock weathering (freeze/thaw or wet/dry cycles)
- Geologic structure (old slips, bedding planes, weak layers)

Generally, forces controlling the shear stress are cyclical events, such as a heavy rainfall, earthquakes or an addition of material from higher upslope (colluvial deposition). Changes in the material strength generally occur continuously over a much longer time period as rocks weather and breakdown, or vegetation grows and slowly strengthens a slope.

Water plays the biggest role in slope failure. It is often mistakenly believed that this is because water 'lubricates' the slope, leading to its failure. However, it is mainly due to the increase in mass on the slope from the water. 100 mm of rain can add up to 100 kg of mass over every square metre of ground if is fully absorbed. When rainfall depths exceed 120 mm, many slopes can become prone to failure. Rainfalls between 40-120 mm may sometimes trigger landslides if antecedent conditions have waterlogged the ground. Antecedent conditions often play a big role in landslide events. The two main types of antecedent conditions that lead to slips in the region are; a wet winter with susceptibility increasing towards the end of the period and; a dry summer with a major rainstorm event producing falls of over 200 mm. On December 20 1976 a succession of moderate intensity storms caused over 200 mm rainfall to fall over the Wellington area. This resulted in over 1400 landslips and millions of dollars worth of damage.

The next most common triggering mechanism is earthquake shaking. The 1855 Wairarapa earthquake triggered landslides over 20,000 km^2 in the southern North Island. These included a 5 million m^3 landslide in the southern Rimutaka Ranges and a 11 million m^3 landslide at Kopuranga that blocked the Ruamahanga River. A lake formed upstream of the landslide dam and later overtopped it. A large earthquake at the end of a wet winter in which the ground is waterlogged has the potential to induce many landslides in the Wellington region.

While most landslides are ultimately triggered by natural events, human modifications to hill sides, especially in urban areas and along transport corridors often promote or exacerbate slope instability. It is not uncommon for old landslides to be reactivated by development and slope modification. Many of the slope failures in the 1976 storm event were old slides reactivated by housing development. Over two thirds of the 74 landslides reported in the region during the February 2004 storms happened on slopes modified by earthworks.

Some of the main human activities that can induce slope failure include:

- *Vegetation clearance*
- *Slope modification (undercutting & steepening)*
- *Poor Engineering (low strength fills, badly designed retaining walls)*
- *Slope overloading (housing, swimming pools)*
- *Poor drainage (concentration off roads, storm water, leaking pipes or swimming pools)*
- *Vibration*
- *Mining or quarry activities (open pit, tunneling)*
- *Combinations of two or more of the above*

Landslides can cause catastrophic failure of lifelines that lie in their path. They can affect all lifelines that are sited on or below steep slopes. Often lifelines are located perpendicular to the landslide hazard making them more vulnerable. Landslides that block rivers or streams can flood upstream assets and cause flash floods if they burst suddenly.

Important transport routes in the region identified as being at high risk to landslide hazard include; the Mount Victoria Tunnel, Happy Valley/Ohiro Road; SH 1 (esp. Ngauranga Gorge and below Pukerua Bay-Paekakariki coastal escarpment) SH 2 (esp. Wellington-Hutt section); SH 58 (Haywards Hill); Makara Road; Akatarawa Road;

Rimutaka Hill Road; numerous local roads through hilly terrain across the region (hill suburbs of Wellington, Lower & Upper Hutt, Eastbourne, hill country of the Wairarapa). Widespread landsliding in the Wellington region will likely be combined with a flooding or earthquake event. A broad scale overview of the landslide risk in the region can be seen in Figure 3.6.1 and Significant landslide events within the region (involving widespread slipping, property damage and/or evacuations) between 1997 and 2007 are given in Table 3.6.1.

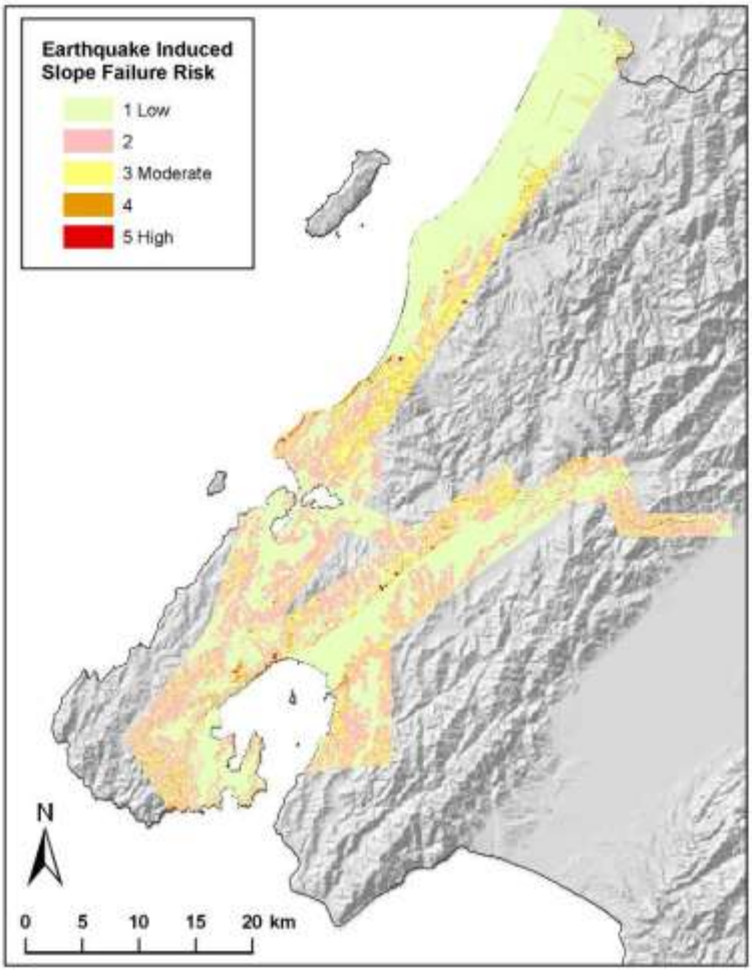

Figure 3.6.1. Earthquake induced slope failure risk in urban areas and transport corridors of the Wellington region.

Table 3.6.1. Landslide events involving widespread slipping, property damage and/or evacuations between 1997 and 2007.

Date	Effects	EQC claims	EQC paid
14 October 1997	Landslide in Upland Road, Kelburn after heavy rain. Houses damaged and three houses evacuated. Caused by excavation of slope.	95 (incl. flood damage)	$256,000 (incl. flood damage)
26 June 1998	Landslides in central Wellington after heavy rain. Properties damaged and people evacuated from Thorndon and Oriental Bay.	106	$392,000

2 July 1998	Numerous landslides around Wellington after heavy rain. SH1 and SH2 and Wellington hill suburbs affected.	127	$193,000
20/21 October 1998	Widespread landslides after heavy rain block, or partially block, many roads including Akatarawa, Paekakariki Hill, Rimutaka Hill, Tuapaka Hill and Otaki Gorge roads. SH1 and the main trunk rail line also affected at Kapiti.	<30	unknown
8 March 1999	Several large landslides (>10,000m^3) at Whatarangi Cliffs, Palliser Bay. Road and baches damaged. Trigger unknown but thought to be human-caused.	<30	unknown
21 July 2001	Numerous landslides after prolonged rain. Car damaged by a soil flow in Northland. Rockfall in Lower Hutt and SH2 partially blocked by landslides at Kaitoke Hill and south side of Rimutaka Hill.	<30	unknown
22 November 2001	Numerous landslides after heavy rain. One lane of SH2 closed at Melling after a rockfall. Landslides block roads at Kelson, Makara Road, Takarau Gorge Road, SH58, Grays Road and Paekakariki.	89	$461,000
10 January 2002	Landslides after heavy rain. Soil flow on The Terrace, three houses evacuated.	36 (incl. flood damage)	$152,000 (incl. flood damage)
9 September 2003	Landslides after heavy rain. House evacuated at Worser Bay, Seatoun after a large (~400m^3) soil slump, SH2 partially blocked on Rimutaka Hill.	<30	unknown
3 October 2003	Widespread landslides after intense rain. Debris flow at Paekakariki inundated a motel, houses, SH1 and the main trunk rail, and 20 homes evacuated. SH2 blocked by numerous landslides between Ngauranga and Petone. Numerous other landslides in the western Hutt hills, between Plimmerton and Pukerua Bay, Paekakariki Hill Road, Transmission Gully, SH58, Bulls Run Road (Upper Hutt), Blue Mountain Road and Rimutaka Road.	119 (incl 13 Oct)	$762,000 (incl 13 Oct)
13 October 2003	Widespread landslides after heavy rain. Roads closed in Wellington and the Wairarapa.		
11/12 February 2004	Widespread landslides after heavy rain. Roads closed in Wellington, Kapiti. Akatarawa and Rimutaka Roads blocked.	37 (11-17 Feb)	$225,000 (11-17 Feb)
14/15 February 2004	Widespread landslides after heavy rain. Roads blocked, or partially blocked, at SH58, Karori, Johnsonville, Gracefield Road, coastal Miramar, Karaka Bay, Korokoro, SH2 Normandale, eastern Hutt Road, Rimutaka Road, Akatarawa Road, Eastbourne cut off. Homes evacuated, garage undermined and car destroyed in Eastbourne, garage threatened on scarp in Korokoro, house at risk on scarp in Stokes Valley. Large soil slide (40,000m^3) at Te Marua blocked the Hutt River forcing it to flow through Te Marua golf course, causing significant damage.		
17 February 2004	House destroyed by landslide after heavy rain.		
18 August 2004	Widespread landslides after heavy rain. Landslides in Lower Hutt, Wainuiomata, Eastbourne, Breaker Bay. Homes threatened and damaged in Porirua and Days Bay. Homes evacuated in Wadestown. Johnsonville and Paraparaumu rail lines closed. Rimutaka Road closed.	270	$2,882,000
5/6 January 2005	Widespread landslides after heavy rain in Kapiti and Hutt Valley.	44	$231,000
30/31 March 2005	Widespread landslides in eastern Wairarapa hill country after heavy rain. Several debris flows in the Orongorongo Valley, one of which dammed the river forming a small lake behind.	unknown	unknown
20 July 2006	House in Eastbourne completely lost and 20 houses evacuated after heavy rain caused slips around the region. Blame partly attributed to building works below the house over-steepening and weakening the slope.	1	150,000

8-10 August 2006	Landslide in Kelson, Lower Hutt leads to complete failure of a slope, 1 house lost and 4 more threatened. Slip caused by a combination of wet antecedent conditions, uncompacted fill and a suspected leaking sewer pipe.	5	$750, 000 (Cost to stabilize slope $1M)
16 August 2006	A landslide behind an apartment block on Oriental Parade caused evacuation of the building and three adjacent dwellings. The lower apartment was badly damaged and repair and stabilisation work took months to complete.	1	unknown
26 August 2006	Multiple failures on the Paekakariki Hill Road lead to its closure for several months. SH 1 was also closed for a short time. Cost of clean up and strengthening works runs into 100's of thousands of dollars. KCDC considers closing the road permanently.	n/a	n/a

3.6.2 Scenarios

Maximum Probable Event

Widespread mass movements around the region (rockfalls and landslides) triggered by a large earthquake at the end of a wet winter. The event causes much damage to property, infrastructure and transport routes into the region. Road and rail links into Wellington and The Hutt Valley are cut off for one to two weeks. Resources to clean up the slides are unavailable within the region and some utilities and road/rail links are unable to be restored. One significant landslide destroys a high occupancy property (apartments or rest home) that requires immediate rescue and in the longer term demolishing. Numerous smaller slides cause millions of dollars worth of damage to properties and business's in Wellington City and the Hutt Valley.

Mid Range Event

Numerous small rainfall induced landslides in all parts of the region. A small number of landslides block essential roads such as SH 1 and SH 2 for a period of three to four days. A small number of properties are destroyed. People are unable to return to their homes for days. Concurrent flooding causes problems in related parts of the region.

3.6.3 Likelihood

Landslides in the Wellington region tend to be medium-high frequency/low-medium impact events. Based on the historical record, there are on average 7 rainfall triggered landslide events every year. Of these, 1-2 are major and 5 are smaller landslide events. A large event generally involves widespread and numerous small (<10,000 m^3) soil/colluvium slides and flows.

Providing estimates on earthquake-triggered landslides is more difficult because of the infrequency of large earthquake events and the lack of data correlating landslips with earthquake events. Earthquake triggered landslides are generally low frequency/high impact events. Strong earthquake shaking of intensity > MM 8 is likely to generate large (>100,000 m^3) bedrock landslides throughout the region. This intensity shaking is expected in the region every 170 years on average.

The susceptibility of an area to mass movement depends on the angle and aspect of the slope, the vegetation cover, the soil or rock characteristics and any modifications carried out on the slope (e.g. cuts, fills, earthworks). Thus, there is large variability across the region. The landslide risk is highest in densely populated hillslope areas where there has been extensive slope modification and where an event has the greatest capacity to cause major damage. Steep hill country where there has been major slope clearance and road cutting are also high risk areas.

The likelihood of significant rainfall events that could trigger landslides also varies enormously between locations in the region. Table 3.6.3 shows differences across the region in rainfall events that could trigger landslides. High risk times are the end of a wet winter or during large scale intense storms, such as ex-tropical cyclones. A moderate sized (M 6.0 +) earthquake occurring during wet periods or a large earthquake (> M 6.5) at any time could trigger a number of mass movements. General rainfall depth and ex-tropical cyclone return periods are:

Rain Depths

- 100 yr return period 1-hour rain depths 40 mm
- 100 yr return period 24 hr rain depths 200 mm

Ex-tropical cyclones

1 every 3 – 6 years with various levels of impact

Table 3.6.6. Differences around the region in heavy rainfall return periods (120 mm) for rainfall events that can trigger landslides.

Rain gauge	Return period of rainfalls exceeding 120 mm in 24 hours
Riverside (northern valley Wairarapa)	*76 years*
Purunui (northeast hill country Wairarapa)	*12 years*
Featherston	*31 years*
Lagoon Hill (southeast hill country Wairarapa)	*4 years*
Karori	*50 years*
Wainuiomata	*3 years*
Paraparaumu	*100 years*
Kaitoke	*5 years*

3.6.4 Growth Statement

It is possible there will be a slight increase in the frequency of landslides triggered by more intense rainstorm events as a result of climate change. There are no indications that there will be an increase in the number of earthquakes that result in slope failures, although Wellington region is in the window for a moderate to large earthquake event.

The vulnerability of communities in landslide prone areas is increasing over time as the population grows and development expands in hill suburbs. Reforestation of steep catchments may reduce the risk over time in some areas.

3.6.5 Urgency Statement

There are numerous landslides every year which result in large financial losses. Only a small number of landslide scenarios would require a CDEM Group response, but the high frequency of events means that this hazards needs to managed. There is the potential for an increase in events due to climate change over the next 100 years.

3.6.6 Consequences

Human

- Small human impact for rainfall induced landslides
- Possibly small number of deaths and rescues necessary from earthquake induced landslides

Economic

- Transportation route blockages
- Loss of earnings
- Reduced productivity of land in rainfall induced events

Social

- Long term displacement for small number of properties affected by landslides
- Commuter disruption

Infrastructure

- Transportation route blockages
- Possible severing of water, sewer, electricity and telecommunication supplies if located in landslide path
- Damage or destruction and loss of private dwellings or other buildings

Geographic

- Erosion of grazing land
- Change of angle of remaining slope after landslide may lead to increased potential of future slides
- Change of topography (e.g. formation of ponds behind the fallen toe of the slide like Hidden Lakes in Wairarapa, or slide materials available as useable land like Hutt Motorway)
- Loss of vegetation
- Loss of productivity

3.6.7 Current Management Mechanisms

There are many ways landslide risk can be mitigated. In many cases, sound planning and good engineering can prevent or reduce the risk of a landslide to an acceptable level. Development on steep, failure prone slopes should be avoided. Despite these measures, slips will still occur in areas with pre-existing development. In these cases, civil defence readiness and response and recovery are still important components of landslide mitigation.

- Planning mechanisms (RPS, District Plans, Soil Plans)
- Rainfall forecasting and monitoring networks
- Geonet network for earthquake detection
- Building Act requirements for engineering stability
- Research of historical events (GNS landslide database)
- GIS based information on landslide susceptible areas
- Transit design and planning of roads
- Soil conservation and planting activities
- Insurance (EQC)

- New landslide management guidelines have been prepared by GNS in a FoRST funded, Geological Hazards and Society programme that will soon be available free for public release.

3.6.8 Possible Future Management Mechanisms

- Identify existing debris fans with development of them for special investigation and management
- Identification of landslide potential up-slope of lifelines and involvement during road development
- Commuter management plan (in progress)
- Regional Road Access Plan for recovery and response after emergency (in progress)

3.6.9 Manageability Statement

There are a large number of mechanisms in place to manage landslide hazard. However, development continues to occur on landslide prone slopes. Sound planning is required to address this issue. Despite the fact that there are many events every year, only a small number require CDEM assistance.

3.7 Drought

3.7.1 Hazard Context/Description

Drought becomes a hazard when people choose to live and derive their livelihoods from land in drought prone areas. There are numerous definitions for a drought, but it generally describes a prolonged period of low rainfall leading to a severe soil moisture deficit. Drought is often accompanied by a extreme high temperatures, that enhance evapotranspiration and exacerbates the effects of the drought on crops and plants. Impacts include water shortages or restrictions, crop failure, damage to horticulture, lack of feed and increasde wildfire potential.

Drought can rapidly lead to a depletion of potable water supplies. Water supply systems have a relatively short storage capacity e.g. Te Marua storage lakes have 20 days of average water use for Upper Hutt, Lower Hutt, Porirua and Wellington. Municipal water demand is usually highest during times of drought as people water gardens/crops to keep plants alive. For a range of reasons, potable water quality is sometimes reduced when supplies run low and thus a potential health risk exits in extreme drought conditions.

The last decade saw three serious droughts in the region. El Niño conditions in the 97/98 summer, with predominant westerlies, mainly affected the Wairarapa. Only 30 to 50 per cent of normal summer rain fell on the eastern hills. The drought was thought to be the worst in almost 100 years in the eastern and central Wairarapa. Water restrictions were put in place and farmers were forced to sell stock. Similar, but less severe conditions over the 2006/07 summer and autumn brought drought to the region again. Farmers were forced to sell stock and in many places drinking water had to be trucked in to bolster dwindling supplies.

The summer/autumn drought of 2000/01, associated with La Niña conditions, primarily affected the Wellington, Hutt and Kapiti areas and, to a lesser degree, southeast Wairarapa. The summer was the driest in Wellington City in almost 100 years, and the driest in Kapiti and the Hutt Valley for 70 and 60 years respectively. In Kapiti, water supplies were restricted and swimming pools were closed. Farmers sold stock and a total fire ban was enforced over the entire Wellington region.

The entire region experienced below average rainfall during the El Niño summer and autumn of 2002-03. Kapiti was the worst affected along with the Tararua Range and the Wairarapa valley. Rainfall between January and March 2003 was only 20-40 per cent of average in Kapiti and Porirua. Irrigation and water supply takes were restricted and Greater Wellington issued water shortage directions in some areas prohibiting water takes other than for domestic or stock use.

Research by Greater Wellington indicates a relationship between the Southern Oscillation Index and seasonal low rainfalls. If El Niño conditions are present in spring, summer rainfall is likely to be below average in the Wairarapa. Figure 3.7.1 shows a soil moisture deficit map developed for the region based on data collected by Greater Wellington, NIWA and the MetService. It can be seen that the areas that become the driest are the western half of the region. In particular, the central Wairarapa and the eastern hill country from Flat Point to Castle Point.

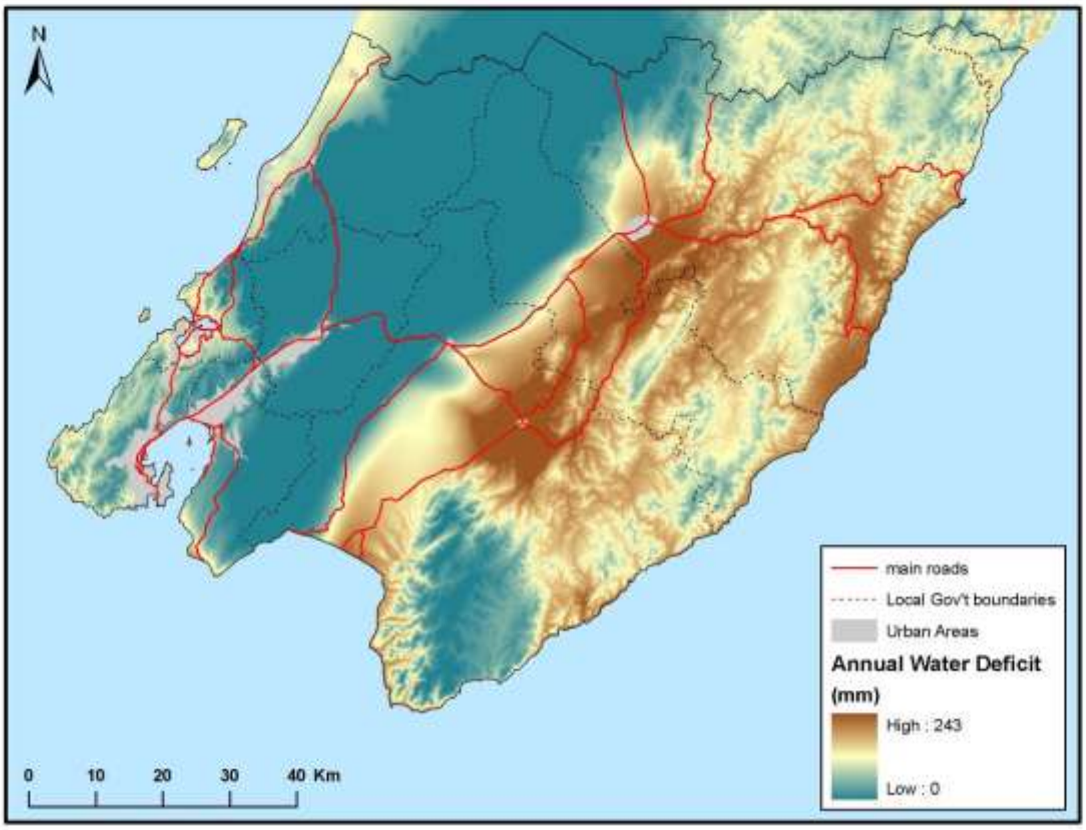

Figure 3.7.1. Annual soil moisture deficit for the Wellington region based on measurement.

3.7.2 Scenarios

Maximum Probable Event

Prolonged drought in the Wairarapa brought on by unusually dry spring that fails to recharge aquifers and exacerbated by strong El Niño conditions through the summer months that cause severe soil moisture deficits. Surface water in rivers dries up in lower catchment areas and wells fall to lowest range. Farmers forced to sell off stock and have to truck in drinking water. Agricultural crops such as grapes severely affected, leading to losses across the district. Drought persists into autumn and begins to affect winter feed crops and impacts on the next growing season. Wildfires break out in locations across the eastern hills and around Upper Hutt leading to further losses. As a result, financial effects are felt for two years and losses run to millions of dollars.

Mid Range Event

Dry El Nino conditions lead to a drought in western areas. In Hutt Valley and Eastbourne, dry conditions lead to a number of wildfires that threaten houses. The prolonged conditions cause water shortages on the Kapiti Coast. The lower course of the Waikanae dries up and the area must rely solely on bore field water supply. This leads to major water restrictions and a slight reduction in water quality as wells start to draw down.

3.7.3 Likelihood

On average there are 15 days per year when soil moisture deficits exceed 130mm in the Wairarapa, and 10 days in Kapiti, Wellington and the Hutt Valley. However, there is significant variation in these figures from year to year.

- The Wairarapa has the highest risk from drought due to its geographical location. In summer months the prevalence of northwest conditions leads to hot, dry föhn winds drying out the Central Valley and eastern hills. The central valley is at most risk because it also often misses out on rainfall from the east. Changing landuse practices in the Wairarapa, such as conversion to diary and vineyards is increasing water demand in this region.

- Water restrictions occur annually on the Kapiti Coast, especially in late summer, due to a combination of dry weather conditions, limited water supplies and high demand.

- Water shortage is only likely in the Wellington metropolitan area during a significant drought.

Medium and long term natural climate variations, such as the El Niño Southern Oscillation (ENSO) and the Interdecadal Pacific Oscillation (IPO) have a measurable impact on local weather patterns. La Niña conditions, with predominant easterly/northeasterly flows, cause lower than average rainfall in Kapiti, the western and southern Tararua Range and the Rimutaka Range. This leads to low flows in the Otaki, Waikanae, Hutt, Wainuiomata and Orongorongo rivers. El Niño conditions, that enhance westerly flows, increase the probability of low summer rainfall in the Wairarapa.

Evidence suggests we are entering a new phase of the IPO which is likely to result in weaker westerly flows over the next 20 to 30 years with more La Niña events. Effects for the Wellington region include increased probability of low flows in Kapiti, Hutt and central Wellington catchments, and decreased probability of drought in the Wairarapa during summer.

3.7.4 Growth Statement

The impact of the hazard will increase as rainfall patterns change due to climate change effects. Periods of drought may become more frequent in some areas and/or more extreme. Modelling indicates that there will be a long term increase in the frequency and strength of west-northwest airflows over the region due to climate change. For the easterly part of the region this means higher temperatures, reduced rainfall, and more hot, dry westerly föhn winds. This may increase the drought risk in the long term in the Wairarapa and lower the risk on the Kapiti Coast.

The vulnerability of communities in already drought prone areas, especially in the Wairarapa will increase over time as demand for water grows due to population growth, and growth in industries such as dairying that require large volumes of water to operate.

3.7.5 Urgency Statement

It is not common for civil defence to become involved in managing the impacts during a drought as it is a slow and creeping type of hazard that is dealt with through planning and management mechanisms. However, in severe conditions drought related hazards, such as wildfire, may require civil defence involvement. As the frequency of droughts may increase over time there is an element of urgency to manage the impacts from this hazard. It is important to maintain alternative water sources during times of drought, especially for rapidly growing areas such as Kapiti and the Wairarapa.

3.7.6 Consequences

Human

- Serious health problems and deaths are possible when the water available drops below that required for human healt and when temperatures exceed normal summer highs.
- Elderly and young particularly at risk

Economic

- Stress on horticulture through soil moisture deficits
- Stress on agriculture through soil moisture deficits and feed shortages
- Severe economic consequences for much of the region, particularly Wairarapa and rural areas

Social

- Alternate water supplies are needed
- Public health issues
- General stress caused by dry and hot conditions
- Activities that require fresh water are reduced e.g. recreation, gardening

Infrastructure

- Water supply restricted, quality may be reduced
- Rail operations affected by extreme heat

Geographic/*Environmental*

- Land becomes vulnerable to wind and runoff erosion
- Productivity of farm land reduced
- Damage to freshwater ecosystems
- Higher risk of fire and consequences if occurs (both rural and urban)
- Increased likelihood of drought with climate change
- Pressure on fresh water ecology
- Soil moisture deficits and feed shortages
- Pressure on native and exotic plant species

3.7.7 Seriousness Statement

This hazard has the largest effect on horticulture and agriculture and domestic water usage. The consequences of drought experienced in New Zealand are not generally life threatening.

3.7.8 Current Management Mechanisms

Timely and accurate climate information is essential for managing the impacts from drought. Soil moisture, rainfall, long range weather forecasts and seasonal climate outlooks can help farmers and water users plan ahead. The efficient use of water for water supply, horticulture and agriculture is particularly important during droughts.

Data is collected from a network of 48 automatic rainfall stations (42 Greater Wellington, 5 MetService and 1 NIWA) and 44 automatic river level monitoring stations (34 Greater Wellington, 9 NIWA, 1 joint Greater Wellington/NIWA). This data is monitored in order to provide drought warnings if necessary. Other management mechanisms include:

- Water conservation and education programs run by local authorities and GW
- KCDC water restriction program
- Long range forecasting and seasonal forecasts from NIWA and MetService
- Monitoring of ground and river levels by GW
- Restrictions on resource consents as droughts worsen
- Regional Freshwater Plan
- Voluntary restrictions adopted by industry
- Railway track monitoring by Tranzrail

3.7.9 Possible future management mechanisms

- Co-ordination with other regions to ensure water standards are comparable so can be used if necessary
- Increased water retention by Councils in supply systems (particularly Kapiti) and by individuals and organisations
- Reduced water demand with sustainable water use policies and education
- Regularly published national drought index to increase awareness of drought and impending drought (McKerchar and Henderson – Natural Hazards Management Conference 2002).
- Better long term forecasting through further research
- Water metering and charging
- New water storage schemes (dams)

3.7.10 Manageability Statement

The meteorological conditions leading to drought conditions cannot be prevented but sound planning and preparation can assist in reducing the consequences of drought. There are a number of mechanisms in place to manage drought hazard and these need to continue and be frequently reassessed in light of potential climate change impacts on the region.

3.8 Fire (Rural)

3.8.1 Hazard Context/Description

Wildfires are relatively common events around the Wellington region. A wildfire is an unplanned blaze that starts in an open space, such as a hillside, as opposed to a house fire. A wildfire hazard is created when it threatens lives, properties or areas with important natural or cultural significance. Wildfires can be started naturally (e.g lightning strike), but more commonly the ignition sources are human in origin. Human causes can be deliberate (arson), accidental (sparks from truck tyre blowout or train) or from careless actions (cigarettes butts, out of control camp fires).

The way a wildfire spreads, its speed and direction of travel, is dependant on a range of environmental factors:

- Fuel (wood, scrub, dry grass/undergrowth)
- Available oxygen
- Weather conditions (wind speed and direction, temperature, humidity)
- Slope angle (very important)

A wildfire requires an ignition source, oxygen and fuel in order to start and spread. Once it has started, other environmental conditions such as weather and slope govern how its spreads. Fires are fanned by strong winds and northwest conditions are particularly effective at forcing wildfires. The slope angle plays an important role in how fast and far a fire can spread. Fires spread rapidly upslope and this can be a major problem in hilly terrain. The problem can be exacerbated by difficult access leading to problems for firefighters combating the blaze, thereby allowing it to spread further. Wildfires are most common between November and March when conditions are generally drier and temperatures higher. Drought conditions during these times can lead to severe fire risk.

Fires can rage out of control in rural areas due to a number of problems. The amount of rural land that can be affected is large compared to the limited resources available to combat fires. Thus, resources can be stretched during a major event or in a bad fire season. Problems can be made worse by the time it takes to get to a fire and by access in difficult terrain. It has been noted by rural fire authorities that there is a trend towards less defensible space around structures in rural areas. Rural fires also pose a high risk hazard to the firefighters combating the blaze. Fires often require the use of helicopters with monsoon buckets, which is also a high risk operation.

Assets at risk during rural fires include above ground utilities, such as power lines, agriculture and horticulture (livestock, forestry and sensitive ecosystems), private dwellings, buildings, business's and recreational facilities.

(a) Fire in the Wellington Region

There have been significant fires in the region in the past. The most serious of these have taken a week to fully extinguish and required all of the rural fire management resources in the region. Past experience has shown that the worst fires have been in gorse. Fires in mature forest have usually been on the margins of these forests where they have been exacerbated by dry gorse. Other significant fires have been in coastal tussock and associated grasslands.

Around 20 per cent of the land of the region (165,500 hectares) in the region is at high to extreme risk from wildfire. This land is characterised by gorse and scrub vegetation, steep slopes, low rainfall and proximity to human habitation.

There were 1,544 separate wildfire incidents in the region between July 1995 and June 2005 with a total of around 1460 hectares of land burnt. Figure 3.8.1 shows the number of wildfires that occurred in the region between 1995 and 2005. It can be seen that there is great variability in the number of fires from year to year, with high fire years generally corresponding with drought conditions. There were a large numbers of wildfires during 1997-98, 2000-01 and 2002-03. These summers were all characterised by hot and dry weather conditions.

Other interesting trends emerge when the number of fires is broken down by region. Figure 3.8.2 show the number of wildfires that occurred during this time (1995-2005) in each individual rural fire authority. The number of fires is not directly related to the amount of area that is burnt. Urban areas tend to have a disproportionate amount of land area burnt in relation to the number of fires. Rural areas tend to have a greater number of smaller fires that affect a smaller area. Masterton, South Wairarapa, and Porirua have the highest number of fires, and a proportionate amount of land is affected by these fires, except Masterton, that has many fires in relation to the small area affected.

The most at-risk areas are the southern and western edges of Wellington, the eastern Hutt hills and areas around Wainuiomata and Eastbourne. In the Wairarapa, the eastern foothills of the Rimutaka and Tararua Ranges, the Cape Palliser coast and parts of the coastal eastern hills are most at risk.

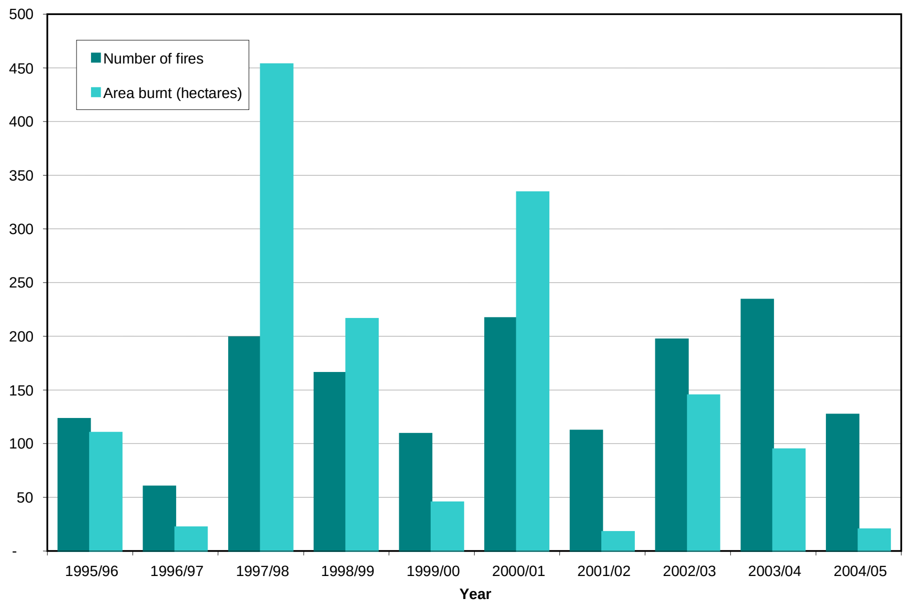

Figure 3.8.1. Number of wildfires and area burnt per year 1995/96 to 2004/05 (source: National Rural Fire Authority).

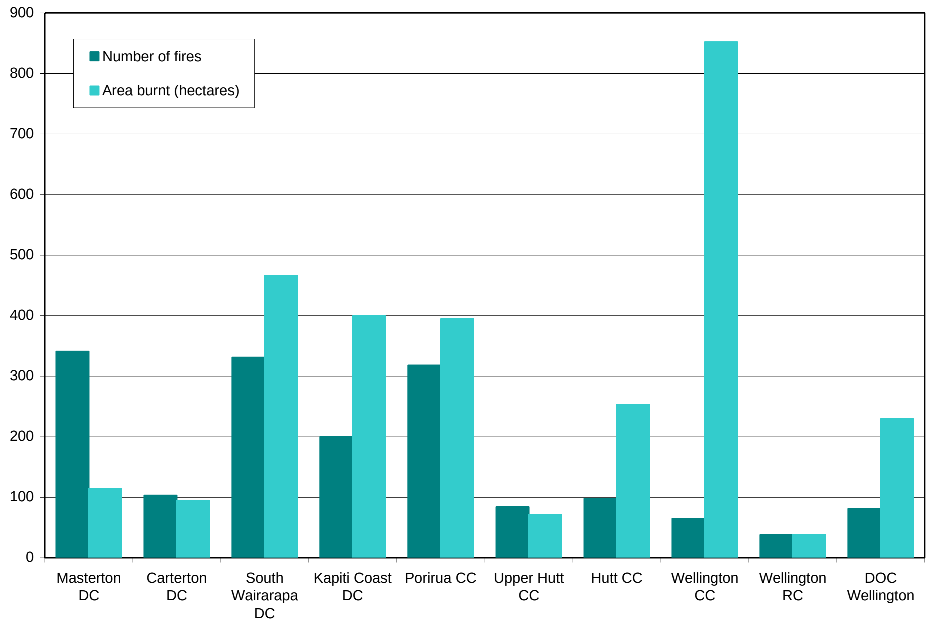

Figure 3.8.2. Number of wildfires and area burnt in each rural fire authority area between 1995 and 2005 (source: National Rural Fire Authority).

3.8.2 Scenarios

Maximum Probable Event

Major fire in extreme drought conditions on rural urban interface, and threatening urban areas. Regional resources fully committed. Widespread evacuations and destruction of property and vegetation. National and international assistance required. Firefighters and residents killed and injured.

Mid Range Event

Three or more medium sized rural fires occur at the same time within the region. Personnel fully committed and support is required from outside the region. Rural properties threatened.

3.8.3 Likelihood

20 % of the regions land is at 'high', 'very high' or 'extreme' risk from wildfire.

3.8.4 Growth Statement

If current climate change modelling remains unchanged, the wildfire hazard is expected to increase. There will be differences across the region. The Wairarapa might be expected to have an increase in the number of wildfires, whilst there may be a slight decline in the Kapiti Coast and Porirua.

Continuing peri-urban development into forested hilly areas (such as Upper Hutt) and rural subdivision means that the fire risk is growing over time. Development increases the number of ignition sources and raises the potential consequences of a wildfire event.

This style of development also tends to have less defensible space around it, which increases the risk.

On a national basis there is a general downward trend in the number of wildfires and area burnt. This is attributed to dedicated volunteer firefighters, public education, better equipment and processes and good cooperation between the National Rural Fire Authority and the New Zealand Fire Service.

3.8.5 Urgency Statement

Wildfires can be expected to occur in the region every year, with the risk higher during hot summers and in times of drought. This hazard requires ongoing management as it has severe impacts on the community.

3.8.6 Consequences

Human

- Deaths possible, in particular on urban/rural interface and rural communities. Comparable overseas events indicate death rates to be low (worst cases measured in the 10's of people, not 100's)
- Injuries including burns, smoke inhalation, breathing disorders likely
- Psychological trauma and fear of recurrent events
- Fire-fighters and aircraft operators particularly vulnerable to death or injury

Economic

- Significant costs of emergency response
- Significant losses to forestry industry (impacts can affect the industry for at least 30 years)
- Airspace restricted causing disruption
- Loss of income in the rural sector
- Insurance implications

Social

- Intense media coverage
- Probable loss of vegetation and agricultural and domestic animals
- Victims may be emergency personnel
- Significant social disruption (smoke, noise, evacuations, road closures)
- Loss of dwelling or income
- Loss of confidence in emergency responders
- Social impacts of deliberately lit fires may include outrage, vengeance, fear, uncertainty

Infrastructure

- Possible disruption to electricity supplies
- Possible disruption to radio communications systems due to smoke effects
- Road disruption due to closures, smoke and/or emergency vehicles

- Significant requirement for water supplies from many sources. Drain on water resources
- Loss of above ground infrastructure

Geographic

- Loss of native bush for recreation
- Possible loss of habitat for some species
- Increased erosion following destruction of vegetation
- Aesthetic impact for many years

3.8.7 Seriousness Statement

Rural fires have the ability to cause great damage and destruction. Risk to human life is not as high as in urban areas, but the economic consequences can be severe if large areas of forestry or farmland are destroyed. One Large or numerous concurrent small fires are able to overwhelm local resources.

3.8.8 Current Management Mechanisms

- Fire Weather Indices, recording and monitoring (Ensis)
- Restricted and Prohibited fire seasons
- Fire permits
- Trained rural fire forces, qualifications standards for rural fire personnel
- Education campaigns for rural and urban fire safety
- Resource consent conditions on forestry development and harvesting
- Ongoing rural fire research programme
- NRFA funding for costs of suppression and subsidies for purchase of necessary equipment
- Training and exercises
- Pre-suppression planning
- Wildfire threat analysis research/project
- Insurance
- Rural Fire Committees for co-ordination (Wellington and Wairarapa)
- Offender rehabilitation

3.8.9 Possible Future Management Mechanisms

- Fuel reduction strategies
- Appropriate training for urban fire-fighters
- Additional personnel for rural fire forces (volunteer shortage)
- Maintenance regimes along side rail tracks
- Domestic sprinkler systems more widespread

3.8.10 Manageability Statement

There are a number of mechanisms in place for managing the rural fire hazard in the region. This is supported by similar resources around New Zealand that could be called in if local resources are taxed.

3.9 Fire (Urban)

3.9.1 Hazard context/Description

Urban fires have the same basic causes as rural fires but have a higher number of human and/or malicious causes. The are numerous human related causes for fires such as; electrical or mechanical faults, ignition of flammable material (petrol, diesel, oil), and industrial accidents to name a few. Urban fires have the potential to cause very costly damage and often result in injuries or death.

The spread of an urban fires is primarily determined by the type of fuels available to burn, which governs the type of fire (house, industrial, chemical), the effectiveness of any response mechanisms such as sprinkler and emergency response time. Most events occur with little or no warning.

High hazard areas are around flammable goods stores (chemical, petrol, oil) and manufacturing and industrial plants that require a lot of heat energy.

3.9.2 Scenarios

Maximum Probable Event

A large conflagration starting in an industrial complex spreading into many buildings with high occupancy and through a whole suburban neighbourhood. Many deaths and homeless, many buildings destroyed. Industrial area destroyed.

Mid Range Event

One large multi-storey building fire. Firefighting resources of the region are fully committed. There are many casualties and fatalities. Some domestic dwellings affected. Welfare provision is necessary.

3.9.3 Likelihood

Many smaller scale events occur each year. There is little information available about the frequency of larger scale events.

3.9.4 Growth Statement

Potential fire ignition sources in urban areas are likely to increase over time as development continues to expand.

The vulnerability of people to fire hazard in urban areas is likely to increase over time due to population growth and density. As infill and medium density housing becomes more popular a greater number of people are placed at risk. However, fire safety mechanisms are becoming more widely used due to education and building code requirements, which is helping to manage the risk.

3.9.5 Urgency Statement

Many urban fires occur every year and therefore it requires ongoing management.

3.9.6 Consequences

Human

- Deaths, injuries
- Potential for death and injuries to fire-fighters
- Possible large number of entrapments
- Psychological trauma
- Burns and inhalation illnesses

Economic

- Complete business loss for those affected
- Employment downtime with ongoing disruption
- Significant costs of emergency response and preparedness (e.g. special suits for fire fighting when hazardous substances involved)
- Large insurance expenses

Social

- Housing damaged and unavailable
- Psychological distress and nuisance of employment downtime and lack of continued habitation
- Communications networks disrupted
- Recreational facilities damaged
- Enquiries needed
- Fear in the case of deliberately lit fires

Infrastructure

- Loss of buildings physically affected. Fire damage, collapse, destruction
- Neighbouring buildings and facilities contaminated
- Irreplaceable industrial processes stopped
- Supply of essential resources stopped e.g. fuel supply

Geographic

- Significant ground contamination and run off due to damaged materials and agents used in fire fighting
- Possible ground destabilisation on slopes

3.9.7 Seriousness Statement

This hazard has the potential to cause major human and economic impacts.

3.9.8 Current Management Mechanisms

- Commercial building fire protection mechanisms
- Building inspections and 'warrants of fitness'
- Fire Safety and Evacuations of Buildings Regulation 1992

- Licensing Act (for occupation rates etc)
- Code of Practice for water supply
- Offender intervention programmes
- Domestic building fire protection
- Public education (especially for schools)
- New Zealand Fire Service preparedness and response activities
- Emergency response plans, equipment and facilities

3.9.9 Possible Future Management Mechanisms

- Continuing and ongoing public education

3.9.10 Manageability Statement

The New Zealand Fire Service has the day to day responsibility for managing and responding to urban fires in the region. They are specifically equipped to carry out this function. The current management activities are therefore high and the there is a clear mechanism for implementing management mechanisms.

3.10 Hazardous Substances

3.10.1 Hazard Context/Description

Hazardous substances have one of the following properties:

- *Explosivity*
- *Flammability (to either heat, air or water)*
- *Oxidative properties*
- *Corrosiveness*
- *Toxicity and or Eco-toxicity*
- *Generate hazardous substances on contact with air or water*

Key substances commonly encountered include:

- **Toxic gases:** phosgene, hydrogen cyanide, hydrogen sulphide, chlorine, sulphur dioxide, ammonia, carbon monoxide.
- **Vapour cloud explosions most commonly caused by:** methane, ether, propane.
- **Most frequently spilled substances:** sulphuric acid, hydrochloric acid, ammonium nitrate, caustic soda (sodium hydroxide), chlorine, sodium/calcium hypochlorite (bleach), petrol/diesel/oil, CNG, natural gas.
- **Most hazardous when spilled:** anhydrous ammonia, benzene/toluene/xylene (carcinogenic), nitric acid, phenol, methanol, chlorine, calcium/sodium hypochlorite.

These substances are stored and transported around the Wellington region and have the potential to harm people and both the built environment and environment.

Toxic gases, such as chlorine and ammonia, may extend up to 2 km downwind. Other hazardous substances such as nitrates, acids, or formaldehyde can also be dangerous. Many chemicals are stored in their purest form which also increases the risk.

Explosives can be located in quarries and at NZ Defence Force sites which are close to residential areas.

Solvents may cause fires and possibly vapour cloud explosions/fireballs. This could be lethal to people within 200 m of the location.

The effects of a hazardous substance spill vary, depending on weather and sea conditions, seasons, nature and mix of substances involved, rate of discharge, containment, location, natural hazards and the state of the substance (solid/liquid/gas). A substance may form a toxic gas or flammable substance depending on its flammability range.

There are significant downstream effects from hazardous substance spills/accidents, including containment and disposal. Some substances that may not be harmful to humans may have significant environmental impacts when spilled such as milk and urea.

3.10.2 Scenarios

Maximum Probable Eevent

A major spill of a chemical which is flammable and toxic in gas form. The spill becomes ignited and a fire ball destroys a large area of industrial estate and possibly residential property. The explosion also releases a large toxic gas cloud over surrounding residential areas. A number of fatalities from the initial explosion and potential for large numbers of casualties and possibly deaths from toxic cloud. An event such as this has the potential to be cause by an LPG explosion.

Mid Range Event

A large hazardous chemical is spilled due to major transportation accident. A localised fire ensues and significant environmental damage is caused by chemicals spilling into waterways. Clean up takes weeks and localised environmental impacts felt for years to decades. This may be a cocktail of substances stored separately when being transported but reacting together during the accident.

3.10.3 Likelihood

There are regular small scale hazardous substances incidents each year.

The risk of fatality from chlorine gas incident is estimated at 3 in a million.

3.10.4 Growth Statement

It is unlikely that there will be less hazardous substances in the region in the future. The amount may stay the same or increase over time.

As urban populations grow, more people may live in close proximity to industrial facilities that store and use hazardous substances. If the number of trips involving hazardous substances increases, this will increase the vulnerability of people to the hazard.

3.10.5 Urgency Statement

Minor incidents involving hazardous substances occur frequently. Major events that result in fatalities are less frequent. The specific details about the possible impacts of this hazard are not thoroughly understood and may be greater or less than is currently estimated.

3.10.6 Consequences

Human

- Deaths
- Injuries
- Burns cases
- Inhalation illnesses
- Paranoia, psychological distress associated with uncertainty about the hazard

Economic

- Major economic losses to industry who use the hazardous substance
- Business disruption in affected areas
- Physical property damage/destruction in affected areas
- Large costs of litigation possible

Social

- Anger towards industry and government
- Disruption of recreational opportunities
- Decontamination may be required
- Isolation of communities for a period of time

Infrastructure

- Disruption to localised transportation networks
- Localised damage in affected areas

Geographic

- Damage to environment, ecosystems, plant and animal species

3.10.7 Seriousness Statement

This hazard has the potential to cause a single incident that has major impacts on a localised area and environment as well as major economic and community disruption.

3.10.8 Current Management Mechanisms

- Resource and discharge consents
- National Poisons centre
- 0800 CHEMCALL
- Decontamination Plans
- Hazardous Substance Technical Liaison Committee
- Emergency Services Co-ordination Committees
- Hazardous substances manifests for all vehicles
- Building and land use consents
- District plans (commercial/residential zoning)
- Emergency responses
- HSNO legislation
- Transit (and contractors) State Highway Spill Response Procedures
- Industry safety standards including transportation and storage

3.10.9 Possible Future Management Mechanisms

- Hazardous substances management plans for all facilities under HSNO legislation. (audited by ERMA approved testers)
- Decontamination plans for hospitals and health care facilities
- Radio scripts pre-prepared for advice during toxic cloud event

- Emergency shut down valves on storage sites
- Relocating storage sites to lower risk areas
- Protect pipelines from damage due to natural hazards or external fires
- Ensure facilities meet NZS:4203 1992 Design loadings for buildings
- Provide bunding to contain spills at storage sites
- Emergency plans and procedures
- Public information/notification about what to do
- Planning measures to introduce separation between hazardous facility and people/environment (MFE guidelines 1995)
- Better methods of storing hazardous substances information when being transported
- Altered transport arrangements (e.g. times, routes etc used)
- Better planning for disposal of contaminated waste
- On site fire fighting and protection facilities and access

3.10.10 Manageability Statement

There are a large number of controls in place for this hazard which mean that in most cases, small emergency events are well managed and controlled. Larger events require concerted co-ordination.

3.11 Transportation Accident

3.11.1 Hazard Context/Description

There are many causes to transport accidents. Some of more common are:

- *human error*
- *mechanical failure*
- *systemic/procedural failure*
- *natural hazard (e.g. earthquake, storm event, flooding, landslide)*

Most accidents are events that occur rapidly and cause maximum effects immediately at the time of accident. Rarely do they have long warning periods. An exception to this might be a ferry accident. How serious an accident may become depends on the number of passengers on board the service. Table 3.11.1 gives passenger capacities for a range of transportation services in the region. Historical incidents suggest that a ferry incident is the most likely cause of a large scale event. Although Wellington airport is surrounded by suburban development, and despite the fact that it is one of the most challenging commercial airports in the world to land at, there is a good safety track record of operations here.

Table 3.11.1. Passenger capacities for transport carriers in the region.

Transportation mode	Capacity
Commuter bus	40
Commuter train (peak Hutt Valley)	752 (4 x ganz at 188 people each) max
Commuter train (off peak)	40
Aratere (Interislander)	50-399 max (freight vs max passenger sailing)
Arahura (Interislander)	1049 max
Kaitaki (Interislander)	1600 max (600 cars)
Santa Regina (Bluebridge)	370 max (150 cars)
Monte Stello (Bluebridge)	370 max
Small aircraft	2-20 people (often 100 % full)
Domestic/Tasman aircraft	**737**:120-140 (average 70-80 % full)
	767: 240 (average 80-90 % full)
Airforce aircraft	**757** - 6 x per week: 228 (average 80 % full)

Event characteristics are likely to include:

- High proportions of injuries and deaths
- Extraction and rescue (land or marine)
- Transportation to medical treatment and on site treatment

- Firefighting
- Scene control and access restrictions
- Destruction of structures in the vicinity of accident (including utility services)
- Disruption to subsequent transportation services
- Possible environmental contamination or secondary hazardous substances incident
- Significant interest and presence of family/ 'meeters and greeters'
- Crime scene investigation
- A large number of emergency services agencies in attendance
- Intense media interest (possibly international also)

The largest transportation accident in the region's history was the Wahine disaster on 10 April 1968. The Wahine, on route from Christchurch, struck Barretts Reef and ran into trouble when it drifted across Wellington Harbour, before finally resting at Seatoun. The ship had been caught in heavy seas and severe weather funnelling through Cook Strait from Cyclone Giselle. Fifty-one people lost their lives in the disaster. Despite the lessons learnt in that disaster, ferry crossings in rough weather continue to cause problems. In 2006, two InterIsland ferry crossing incidents caused damage to cargo and injuries to passengers and crew. The more serious of the two occurred on March 3. With 391 passengers on board, a decision was made to cross Cook Strait with 8-10 m swells and gale force winds. There were reports of two 14 m waves striking the ship, causing it to roll 50 degrees and putting it close to capsizing off Cape Terawhiti. In the event, 4 passengers and crew were injured and 6 rail wagons, 32 cars and 15 trucks were damaged.

3.11.2 Scenarios

Maximum Probable Event

A fully laden 737 crashes into a residential area of Wellington city during a northwest storm event or an InterIsland Ferry sailing at full passenger capacity capsizes in Cook Strait.

Mid Range Event

A train derails at high speed on the Hutt Valley line during peak hour. Contact is made with numerous stationary objects and a fire is started. Results in a high number of fatalities and most other passengers requiring medical treatment. Over 150 people hospitalised.

3.11.3 Likelihood

Each day there are a large number of passenger trips taken without incident. The occurrences of small scale events and near misses indicate that there the possibility exists for a larger scale event to occur.

No information was found on the rate of major accident occurrences.

3.11.4 Growth Statement

The number of accidents is unlikely to increase over time. Road and rail infrastructural improvements are making transport networks safer to travel on. In addition, safety campaigning is helping to reduce motor vehicle accident fatalities.

Safety requirements for large commercial operators are under constant scrutiny and are improving over time. Considerable work has been undertaken to improve the safety of Wellington Airport. Recent incidents in Cook Strait have resulted in updated guidelines for maintaining safety and assessing sailing conditions in the Strait.

3.11.5 Urgency Statement

When they occur, responding to transport accidents is a matter of extreme urgency. Many response procedures need to be agreed upon in advance, as usually there is no warning time.

3.11.6 Consequences

Human

- Deaths
- Injuries (including possibly crush and burns cases)
- Psychological distress for responders and primary victims

Economic

- Loss of confidence in the transportation sector affected
- Business disruption and possible shut down
- Large costs of response and investigation (esp. if recovery of vessel, craft necessary)

Social

- Temporary and permanent family disruption
- Commuter and transportation systems disrupted

Infrastructure

- Damage to physical transportation mechanisms (e.g. roads/rail lines) or vehicles - e.g. ships or planes.
- Possible damage to infrastructure in the vicinity of the accident

Geographic

- Possible ground or marine contamination from fuel or chemicals

3.11.7 Seriousness Statement

A single transportation accident can have significant human impacts

3.11.8 Current Management Mechanisms

- WIAL First Impact co-ordination committee
- WIAL emergency alerting system
- WIAL Emergency plans and procedures
- Airport crash exercises
- Cook Straight Ferry Emergency Plans
- Ferry emergency exercises and drills
- Wellington Metropolitan and Marlborough Ship Emergency Plan (NZ Police)
- InterIsland Line Shore Response to Ship Emergency Plan
- Rimutaka Tunnel emergency response plan and exercises
- Oil Spill Response Plans
- Beacon Hill ship control
- Search and Rescue (Sea and Urban)

3.11.9 Possible Future Management Mechanisms

- Commuter management plans for delays and disruptions

3.11.10 Manageability Statement

There are a considerable number of management mechanisms in place to address this hazard. Most of the management mechanisms are part of normal safe business operating procedures and therefore have a low level of difficulty to implement.

3.12 Biological/Pandemic

3.12.1 Hazard Context/Description

A pandemic is an epidemic (an outbreak of an infectious disease) that spreads across a large region (for example a country), or even worldwide. A pandemic can start when three conditions have been met:

- The emergence of a disease new to the population or the re-emergence of an old, highly infectious and fatal disease.
- The agent infects humans, causing serious illness.
- The agent spreads easily and sustainably among humans.

A disease is not defined as a pandemic simply because it is widespread or kills a large number of people; it must also be infectious. Cancer is responsible for a large number of deaths but is not considered a pandemic because the disease is not infectious. However, a new strain of influenza could result in a major pandemic.

Public health emergencies are primarily generated by communicable diseases, food and waterborne illnesses and the physical environment (e.g. hazardous substances or biosecurity). These are biological and environmental hazards that affect humans.

Significant public health effects occur when the rate of illness is greater than the existing health system response can manage.

There are a number of scenarios that would require a Public Health Authority response:

- New and emerging diseases affecting humans (SARS, new influenza strain or antibiotic resistant bacteria e.g. MRSA)
- Bioterrorism using biological agents such as anthrax and smallpox (other agents such as cyanide or chemical warfare would be led by another agency although public health would be involved)
- Major contamination of metropolitan water supply leading to communicable disease outbreaks such as cryptosporidium, salmonella, giardia, or E-coli contamination.
- Mosquito-borne illnesses. NZ already has a mosquito species established that could carry Ross River Virus. Diseases such as Yellow Fever, Dengue Fever and Malaria could become endemic in New Zealand if other mosquito vector species are allowed to establish.
- Large outbreak of a severe communicable disease, including meningitis, VTEC, measles, ebola.
- Severe and prolonged heat wave or cold spell.

(a) Avian Influenza Virus (Bird Flu)

Currently world health authorities, including in New Zealand, are keeping a watching brief on the spread of H5N1, a virulent strain of influenza found in bird populations. The strain was first detected in 1996 in China and a year later caused a large outbreak amongst poultry in Hong Kong, that also infected 18 people. Despite an intensive effort to exterminate the virus, it resurfaced 6 years later in 2003, with a more adaptable mutation able to withstand harsher conditions. The H5N1 strain is able to infect humans (i.e. cross the species barrier), but it is not yet easily communicable from human to human.

There are fears that H5N1 may acquire a mutation enabling it to spread easily from human to human contact, especially through airborne particles. The strain has been found in bird populations across Asia (where it originated from) and Europe (incl. most recently the UK). It has already killed over 60% of people who have contracted the virus and in some places, such as Indonesia, almost 80% of people who have contracted the virus have died. Since 2003, H5N1 has infected 329 people in 12 countries, of which 201 subsequently died.

Presently, a new mutation has been identified in the virus that allows it to survive in the upper respiratory tract of humans. Earlier strains of the virus have not survived easily in this part of the body, because it is too cool for the virus, effectively slowing its spread in humans. However, this new strain can survive in cooler temperatures and is the next step in H5N1 acquiring the ability to be easily transmitted from human to human.

The World Health Organization (WHO) has developed a global influenza preparedness plan, which defines the stages of a pandemic, outlines the role of WHO, and makes recommendations for national measures before and during a pandemic. The phases are:

Interpandemic period:

Phase 1: No new influenza virus subtypes have been detected in humans.

Phase 2: No new influenza virus subtypes have been detected in humans, but an animal variant threatens human disease.

Pandemic alert period:

Phase 3: Human infection(s) with a new subtype but no human-to-human spread.

Phase 4: Small cluster(s) with limited localized human-to-human transmission

Phase 5: Larger cluster(s) but human-to-human spread still localized.

Pandemic period:

Phase 6: Pandemic: increased and sustained transmission in general population.

At the moment WHO has set the alert level for H5N1 at Phase 3; human infections with a new subtype but no human-to-human spread. However, there have been unsubstantiated cases in China and Europe of this virus spreading from human to human.

(b) Superbugs

Antibiotic-resistant *superbugs* may also revive diseases previously regarded as ‘conquered’. Cases of tuberculosis resistant to all traditionally effective treatments have emerged to the great concern of health professionals.

Some common bacteria, like Staphylococcus aureus, have developed resistance to the strongest available antibiotics, such as vancomycin. Commonly referred to as MRSA, this has emerged in the past 20 years as an important cause of hospital-acquired infections, that are now colonizing and causing disease in the general population.

3.12.2 Scenarios

Maximum Probable Event

A major influenza pandemic (H5N1) occurs and over a period of 6-12 months. 10's of thousands of people are infected and 1000's die. This overwhelms all hospital and health services, health practitioners themselves are affected and therefore unable to provide service. International assistance is needed, however this influenza strain is affecting many other countries. The economy slumps, leading to a small recession as local and international travel is limited and businesses are unable to operate.

Mid Range Event

A large outbreak of a severe communicable disease for which treatment is available but which results in hospitalisations and a number of deaths. Especially vulnerable are children and elderly.

3.12.3 Likelihood

There were three influenza pandemics in the 20th century that overwhelmed health and social services either regionally or internationally. The influenza pandemic in 1919-20 caused 20-40 million deaths.

As a rough estimate a mid-range event could be expected every 20-30 years.

3.12.4 Growth Statement

The possibility of new and emerging diseases is increasing, due to access to international travel and environmental pressures. The possibility of bioterrorist activities has also increased significantly as has agency response planning and public awareness around this issue. Ageing infrastructure may also contribute to an increase in occurrence of events affecting water supply. As the population ages people will become more vulnerable to the effects of infectious illnesses and pandemics.

There is the possibility that infectious diseases are becoming more common due to population growth, new diseases jumping the species barrier and through old diseases mutating to acquire new virulence that cannot be treated with traditional medicines.

Climate change may allow the range of tropical diseases to spread into more temperate regions. New Zealand may acquire diseases from Australia that are spread by mosquito.

Some of these effects are offset by advances in medical technology and coordinated international planning and response mechanisms.

3.12.5 Urgency Statement

Conditions for a worldwide influenza pandemic are finely balanced at present. There is a high level of urgency in preparing for this. Currently we sit at phase 3, the first step in the pandemic alert level.

New Zealand has recently experinced a small menangitis epidemic that is being brought under control, but outbreaks are still occuring every winter. Most recently there have been outbreaks of TB, a disease previosly thought of as a 'third world disease'.

3.12.6 Consequences

Human

- Large number of deaths possible.
- Particularly vulnerable are those with low immunity, the aged and the young
- Many people ill and requiring medical attention.
- Health services for other conditions may be compromised
- Other public health priorities also compromised.

Economic

- Large costs of emergency response
- Losses from shutdown of businesses affected
- Secondary economic effects through reduction in international and local travel and trade, nervousness in stock market and business in general

Social

- Loss of ability to work for large portion of the workforce
- Psychological impacts including fear and confusion, paranoia and other trauma
- Stigma of communicable illness placed on those affected
- Reduced quality of life, nuisance factors
- Loss of community cohesion as travel and contact limited
- Large demand for information
- Disproportionate impact on disadvantaged and vulnerable groups where there is crowding and lower baseline health status

Infrastructure

- Dependant on circumstance and may include water supply shortages, power outages, ports and airports shut down or reduced capacity
- Staff infrastructure and the performance of essential services e.g. hospitals, emergency services, council activities, public health etc. may be ill and so there is reduced capacity to deliver normal services.

Geographic

- None to note

3.12.7 Seriousness Statement

These events have the potential to severely disrupt society

3.12.8 Current Management Mechanisms

- Standards and audits of water treatment facilities
- NZ Drinking Water Standards 2000
- Regional Public Health Pandemic Plan
- Mosquito Surveillance and Response Plan
- Ministry project group NECAP (Novel Emerging Infectious Disease Clinical Action Plan). Set up to produce a clinical action plan for emerging novel infectious diseases by June 2004.
- Training and exercises
- Council asset management plans
- Relevant legislation (Health Act, Biosecurity Act etc.)

3.12.9 Possible Future Management Mechanisms

- National health emergency management plan.
- Local risk management plans for areas identified as particularly vulnerable or in need of asset renewal
- Water providers risk management plans
- Drinking water assessors to be implemented

3.12.10 Manageability Statement

Many management mechanisms are in place. These are co-ordinated regionally by Regional Public Health. This agency is capable of dealing with most commonly occurring public health issues. Public Health services across New Zealand are well linked and can call on other areas to provide assistance in emergency situations. The ability of these services to manage larger events relies on co-ordination with many other non-health agencies who may not yet understand their part in these types of incidents.

3.13 Agricultural Hazards (Biological)

3.13.1 Hazard Context/Description

The types of incursions for emergencies that would involve a whole of government response are those that will:

- severely affect production, trade, public health and/or biodiversity
- cannot be managed under Biosecurity Act Part VI powers and require emergency powers as provided in Part VII or other legislation
- where more resources are needed than existing service suppliers can provide
- where the Government requests a whole of government approach
- where public concern exceeds technical issues which MAF could manage with existing powers.

Specific diseases that could occur include anthrax, avian and horse influenza strains that affect humans (bird flu), bovine spongioform encephalopathy (mad cow disease) or other encephalopathies such as scrapie in sheep or chronic wasting disease in deer, rabies and foot-and-mouth disease.

3.13.2 Scenarios

Maximum Probable Event

A major epidemic of foot-and-mouth disease dispersed across both islands prior to detection and imposition of movement control restrictions, such as occurred in the UK in 2001. Such an outbreak would require over 5,000 staff in four weeks with an estimated 300,000 animals requiring slaughter and disposal.

An outbreak of this scale would overwhelm veterinary and contracted response service suppliers. Recruitment from other sources and international assistance would be urgent and necessary. The economy would be seriously affected as all export of animals and animal products would have ceased. Animal welfare problems would exist on properties as they would be overstocked with animals for which there is no market and insufficient feed.

Mid Range Event

A number of cases of anthrax are detected on the banks of a river anywhere in New Zealand. While anthrax is endemic with sporadic incidence in many countries, the disease has not been diagnosed in New Zealand since 1954 and is now treated as exotic. Anthrax affects animals and humans, and may be fatal, so is considered a serious public health risk. An incursion would require significant public communications assuring the safety of the New Zealand meat products. Trade would also be severely affected. Public health officials will be overwhelmed with the demand for information.

3.13.3 Likelihood

Foot and Mouth Disease has never occurred in New Zealand. The threat is still present and recent outbreaks have been experienced in Taiwan 1997 (free since 1929), South

Africa 2000 (free since 1956 in domestic livestock), South Korea 2000 (free since 1934), Japan 2000 (free since 1908) and the UK (free since 1967).

Midrange event such as anthrax, formerly present in New Zealand and abundant in other countries or avian influenza with a strain that affects humans have greater probability. Bird Flu is present in a number of places around the world. Human to human transmission of avian influenzas is thought to be extremely limited. The exact mode of transmission from birds to humans is not known.

3.13.4 Growth Statement

The possibility of introduction of diseases present in the countries of trading partners as well as new and emerging diseases are increasing, due to increased travel and environmental pressures.

The possibility of bioterrorist activities targeted at agriculture has also increased significantly as has response planning and public awareness around this issue.

3.13.5 Urgency Statement

Conditions for exotic disease incursions in animals could possibly increase. Climate change may hasten the spread of diseases previously confined to warmer regions. It is important to remain alert to possible incursions, especially in response to new strains and agents occur internationally.

3.13.6 Consequences

Human

- Public concern and panic are greater than actual human illness or death from zoonotics as a relatively small proportion of the population interact routinely with livestock and poultry.
- Food safety issues will come to the forefront with diseases such as anthrax, bovine spongioform encephalopathy or other transmissible encephalopathies of animals due to the linkage with new variant Creutzfeldt Jakob (CJD) disease, a degenerative fatal human encephalopathy.
- Other public health priorities also compromised.

Economic

For Foot-and-Mouth Disease:

- a loss of GDP $6 billion in first year; $10 billion after 2 years
- 8% drop in export of goods and services in first year
- loss would continue because output lowered and exacerbated by slumps in domestic demand and negative reaction of trading partners
- 20% drop in exchange rate, recovering over ~ 2 1/2 years
- reduced overseas and local investment (short term by 20%, longer term 6%)
- reduced tax revenue $3.5 billion over 4 years
- doubling of net debt (2009/10 projected 12.1%, rises to 25.6%)

- Cost of emergency response to the outbreak = $200 million includes controlling outbreak & compensating for animals slaughtered
- Tourism drop could be significant (In UK 2001 tourism was impacted 10 times that of primary production sector)

Social

For Foot-and-Mouth Disease

- 15-20,000 increase in unemployed
- reduced household wealth due to drop in exchange rate and investment
- Loss of ability to work for large portion of the workforce
- Psychological impacts including fear and confusion, paranoia and other trauma
- Stigma of biosecurity breakdown placed on those affected
- Loss of rural community fabric due to devastation of rural economy

Infrastructure

- Challenges on infrastructure are dependant on circumstance
- Demands on water supply due to the need for cleaning and disinfection for conveyances and for premises decontamination
- heavy equipment demands
- demand on municipal landfill for disposal of potentially infected material
- biosecure transport of carcasses over public roads to mass burial sites.

Geographic

- Dairy impacts in Waikato, Taranaki, Southland
- Sheep and beef impacts in South Island - Otago, Southland.
- Poultry and pig impacts around Auckland and Christchurch.
- environmental degradation due to carcass disposal

3.13.7 Seriousness Statement

These events have the potential to severely disrupt society.

3.13.8 Current Management Mechanisms

- MAF Standards, Procedures and Industry specifications
- MAF contracts with EDR suppliers and expert veterinary services (Massey)
- EDR suppliers contingency stores
- Animal Biosecurity Consultative Committee
- Technical Advisory Group – *ad hoc* multidisciplinary group of experts
- Domestic and External Security Co-ordination (DESC) framework
- Training and exercises
- Relevant legislation (Biosecurity Act 1993.)

- MAF's Policy statement on responding to an exotic organism incurison [http://www.maf.govt.nz/biosecurity/pests-diseases/index.htm]
- "Notifiable Organisms" and "Other Exotic Oransims" categorisation as per MAF Policy on Unwanted Organisms for the Purposes of the Biosecurity Act 1993

[http://www.maf.govt.nz/biosecurity/pests-diseases/registers-lists/unwanted-organisms/index.htm]

- Standards, procedures and contractual arrangements with response service suppliers to provide capability to investigate and respond to suspected incursions of exotic organisms (24 hours a day, 365 days a year).
- *MAF Biosecurity Authority Standard 153 Exotic Disease Programmes of Animals (including honey bees and fish)* June 2003 [http://www.maf.govt.nz/biosecurity/pests-diseases/animals/standards/153-draft.pdf]

3.13.9 Possible Future Management Mechanisms

- National emergency management plan.

3.13.10 Manageability Statement

Many management mechanisms are in place. These are co-ordinated centrally by the Chief Technical Officer using procedures described in MAF's documented standards and procedures. Integral to the response is MAF's National Centre for Disease Investigation which becomes the Exotic Disease Response Centre (EDRC) in the event of an incursion response. The EDRC is activated for all incursion responses under MAF jurisdiction. It is well co-ordinated and experienced with contracted supplier organisations. Specific financial appropriation is required for delivery of any response. Obtaining the financial resources may require inter-departmental co-ordination.

3.14 Infrastructure Systems Failure

3.14.1 Hazard Context/Description

Could be a failure of any lifeline utility service that affects a significant part of the Wellington region. This includes:

- Water supply
- Wastewater systems
- Electrical supply
- Gas supply
- Telecommunications (including radio) system
- Transportation centres or routes (port, airport, highways, rail systems)
- Fuel supply
- Information technology and financial systems

Failure may be due to internal systemic failure and may be accidental or deliberate. Failures of particular consequence are those of a single asset with minimal redundancy that directly impacts on other utilities (possibly leading to cascading failure). Examples would be gas or electricity failure. Multiple simultaneous failures are also possible. Some lifelines utilities have multiple pathways to deliver their service (e.g. telecommunications, electricity). Failures of systems can lead to overload and large scale social and economic disruption, especially in the electricity grid where it is vital to balance supply with demand. The consequences and recovery may be long term.

Natural events may also be associated with a failure. A major earthquake could lead to disruption of all of these utilities, lightening strikes can knock electricity grids, storms and flooding can disrupt transport routes.

In 2006 a gas supply problem caused disruption to business's in the Wellington CBD that resulted in repairs that took moths to fix.

3.14.2 Scenarios

Maximum Probable Event

Major rupture of gas lines close to boundary into Wellington region. Lack of reserves leads to failure of supply. Widespread effects across region for private residential users and business's. Economic losses for business's relying on gas supply. Problem takes 2-3 weeks to return to normal.

Mid Range Event

Telecommunications failure of a significant duration that affects the ability to dial '111'.

3.14.3 Likelihood

There is no information available to determine the liklehood of these types of events.

3.14.4 Growth Statement

There is no documented evidence to suggest that these events will become more frequent over time. While utilities carry out ongoing maintenance and planning as part of their normal business procedures, in some areas there has been inadequate asset renewal which may lead to increased frequency of events as the systems age. There is also increased congestion in road corridors.

The vulnerability of the community to these events is likely to increase as people and businesses become more reliant on these services, especially electricity failure. There is also significant interdependence between utilities. For example, water supply requires electricity to be pumped.

3.14.5 Urgency Statement

This hazard has arisen as technology has developed and people become more reliant on utility services. This trend is likely to continue. Infrastructure failure may have an element of urgency as the infrastructure in place reaches the end of its life-span and is replaced.

Some infrastructure may be more robust and able to withstand natural hazard events in the period after replacement.

3.14.6 Consequences

Human

- Illness and disease with breakdown in water, waste or heating systems
- Fatalities possible due to inhalation of gas, or fires and explosions caused by failure of gas or fuel systems

Economic

- Business and industry disruption – the utilities themselves and those that rely on the utilities
- Cost of containment in case of failure of sewerage or gas systems
- Tourism industry major losses through loss of appeal as tourist destination
- Loss of employment for businesses forced to shut/close
- Loss of income for industries dependent on transportation facilities (e.g. ports, airports) including export and import industries. Long term economic effects
- Large costs of repair of infrastructure that failed
- Forced vacation of business premises

Social

- Sanitation and biological effects
- Evacuations and inconvenience of loss of gas for cooking/water heating in gas system failure
- Evacuation of large areas if gas spreads through underground corridors
- Possible loss of communication to emergency service providers
- Loss of confidence in infrastructure

- Social disorder due to loss of petroleum run transport systems, panic buying and congestion at fuel service sites

Infrastructure

- Overloading of parts of systems that remain operational (e.g. sewerage overflow, remaining telecommunications sites)
- Physical damage to infrastructure possible
- Long term lack of supply during recovery
- Lack of supplies and personnel (or access of these things to the region) for efficient repair
- One system failure may trigger cascading failure of other systems
- Fires and explosions possible if failure of fuel or gas systems

Geographic

- Coastal or marine pollution with waste water or fuel system failures

3.14.7 Seriousness Statement

Infrastructure failure may lead to significant human impacts depending on the scenario. Failures will definitely have significant economic and social impacts.

3.14.8 Current Management Mechanisms

- Utility asset management plans
- Business/corporate continuity plans
- Service continuity plans
- Redundancy in system design
- Operational emergency response plans
- LTCCP planning

3.14.9 Possible Future Management Mechanisms

- Emphasis on risk management through asset management renewal plans
- Support of Lifelines Group activities
- Further development of Lifelines Co-ordination/Information Centre
- Further development of communications between Lifelines
- Mutual Aid Agreements
- Contractor arrangements
- Consistent risk level terminology

3.14.10 Manageability Statement

This hazard is managed as part of the ongoing business operations of the relevant utility providers. There are many solutions and options for managing these risks.

3.15 Terrorism

3.15.1 Hazard Context/Description

Terrorist actions include actual or threatened:

- o explosive devices
- o harmful chemical release
- o harmful biological release
- o radiological event (incl nuclear)
- o hostage or siege situation
- o product contamination
- o suicide bombers

The methods used during terrorist activities change and evolve over time.

Targets of terrorism:

- An individual target, or multiple significant targets (normally targets are specific rather than general)
- Ports and airports
- Infrastructure including hospitals, fuel supplies, lifelines, Council offices, command and control centres
- Transportation facilities e.g. train stations
- Political or diplomatic
- Any target that would cause economic disruption including imports/exports, tourism etc
- Media grabbing situations e.g. NZ or overseas icons, planes
- Maximum casualty sites e.g. cinemas, stadiums

Most acts of terrorism are designed for maximum effect especially through economic disruption. This may be achieved by killing people or destroying the infrastructure needed for normal economic activities.

Most acts of terrorism involve long term pre-planning. Terrorists often act individually or in small, mobile groups. New Zealand is an unlikely target for Islamic extremists, but disaffected groups may copy terrorist methods to attract attention to their cause.

The scenes of terrorist acts are investigated as crime scenes by the NZ Police and therefore result in considerable ongoing disruption to activities that were occurring in the localised vicinity of the event.

3.15.2 Scenarios

Maximum Probable Event

A dirty bomb with chemical or biological agents is set off in Wellington City. 50 or more people are killed and thousands injured.

Mid Range Event

A terrorist act is carried out against Wellington waterfront in the vicinity of the central train station and the Port. Tens of people are killed and many injured. Access around the crime scene is restricted. Wellington train systems are stopped for a period of weeks and Port operations for a month.

3.15.3 Likelihood

There is no information available about how frequently these events can be expected to occur. Incidents or threats of lower level terrorist activity occur every year.

3.15.4 Growth Statement

The threat of terrorist activities will continue to be elevated in the future. Internationally the profile of terrorist activities is growing. Local activity could arise as a result of specific regional issues acting as a trigger for terrorist activities to be planned (environmental activists or grievance against government).

There is no evidence to suggest that the exposure of the people of the Wellington region will increase.

3.15.5 Urgency Statement

The terrorist threat ebb and flow in response to international and regional events. A specific trigger can cause an increased urgency for this hazard at any time.

3.15.6 Consequences

Human

- Deaths
- Injuries and long term rehabilitation
- Psychological distress

Economic

- Huge disruption to normal economic functioning (may be the specific motivation of the event to cause maximum economic losses)

Social

- Fear and psychological distress
- Displacement of residents and businesses in affected areas
- Loss of institutional knowledge

- Isolation of affected area for crime scene investigation.

Infrastructure

- Transportation disruption
- Possible loss of emergency control facilities if targeted
- Infrastructure may be specific target

Geographic

- None noted

3.15.7 Seriousness Statement

The impact or threat of a terrorist act is considerable both in terms of the actual event itself and of the long term consequences and disruption.

3.15.8 Current Management Mechanisms

- Response planning, exercises and co-ordination
- National terrorism plan (includes recovery aspects)
- International freight systems for reducing the possibility of terrorist acts
- International threat assessment ratings
- Terrorism Suppression Act 2002 Terrorism Emergency Powers Act
- VIP, major event contingency plans
- Trained criminal investigators

3.15.9 Possible Future Management Mechanisms

- Arrangements for increased number of investigators from NZ or overseas

3.15.10 Manageability Statement

There are a growing number of management mechanisms for the terrorism hazard. It will be a hazard that is difficult to prevent or manage due to the considerable pre-planning undertaken to effect terrorism acts and the psychological mentality of people who commit acts of terror.

4. Appendix 1 - Hazard and Risk Rating

4.1 Hazard and Risk Rating Results

The hazard and risk rating is in two parts:

- The likelihood and consequences ratings are useful to give us an indication of the overall risk the hazard may pose.
- The SMUG analysis then looks in more detail at aspects of likelihood (e.g. growth, urgency, manageability) and consequences (seriousness of human, economic, social, infrastructure and geographic effects).

The risk ratings reflect more than just how badly the hazard can affect us (seriousness).

The ratings take into account how much we have already done to manage the hazards and how difficult it is for us to do more about them (manageability).

The ratings also take into account how likely the hazards are to occur (urgency), and whether they, or their consequences, are going to become more frequent (growth).

4.2 Assumptions and limitations

The following assumptions and limitations should be taken into account when considering the hazard and risk analysis ratings.

- The maximum likely event scenario was used as the basis of comparison across all hazards.
- Emergencies for which the CDEM Group is not the lead agency have been considered only at the level that the CDEM Group would be involved.
- Management activities taken during Reduction, Readiness, Response and Recovery have been allocated equal weighting.
- Seriousness, Manageability, Urgency and Growth have been weighted equally in this assessment.
- Some information was not available to form the basis of the rating system (particularly about likelihood and urgency), so ratings in these cases were the subjective view of a group of practitioners in the relevant field.

4.3 Hazard and Risk Ratings Results

Hazard (and brief outline of scenario used)	Likeli-hood	Conse-quence	Initial Risk Rating	S							M	U	G	Risk Rating
				H	E	S	I	G	Total	Ave				
Earthquake – Wellington Fault event	D	5	Extreme	5	5	5	5	4	24.0	4.8	4	4	3	15.8
Pandemic/Emerging disease - SARS, influenza etc	C	4	Extreme	4	4	4	2	1	15.0	3.0	3	3	4	13.0
Storm – rain/wind/hail/lightning	B	3	High	3	3	3	3	2	14.0	2.8	2	4	4	12.8
Flooding – Hutt River 440 year event	D	4	High	3	4	4	4	3	18.0	3.6	3	2	4	12.6
Storm surge & coastal erosion – affecting multiple parts of the coastline.	B	3	High	2	2	2	2	4	12.0	2.4	3	3	4	12.4
Tsunami – locally generated	C	4	Extreme	4	4	4	3	2	17.0	3.4	4	3	2	12.4
Drought - water deficit and extreme heat effects	C	3	High	3	4	3	3	3	16.0	3.2	2	2	4	11.2
Landslide - multiple incidents, isolates area, affects occupied area	D	3	Medium	3	3	3	3	4	16.0	3.2	3	3	2	11.2
Rural Fire - urban/rural interface	B	4	Extreme	3	3	3	2	2	13.0	2.6	2	3	3	10.6
Public Health - mosquito/water borne illness, food safety issue	B	3	High	4	2	3	1	3	13.0	2.6	2	4	2	10.6
Haz Sub - LPG incident - explosion and gas cloud	C	3	High	3	2	3	3	2	13.0	2.6	2	3	3	10.6
Agricultural	C	3	High	2	4	3	1	3	13.0	2.6	2	4	2	10.6
Tsunami - distant source	C	3	High	3	3	2	2	2	12.0	2.4	3	3	2	10.4

Infrastructure failure of IT - affecting lifelines and essential services	C	3	High	2	3	2	3	1	11.0	2.2	2	3	3	10.2
Terrorism – bomb in urban area	D	4	High	4	4	3	3	1	15.0	3.0	3	2	2	10.0
Infrastructure failure – Loss of gas supply close to Region	C	2 to 3	Medium – High	2	4	4	4	1	15.0	3.0	3	3	1	10.0
Urban Fire – industrial to urban area	C	3	High	3	3	3	2	2	13.0	2.6	2	3	2	9.6
Infrastructure failure of water – affected by biological agent	C	3	High	3	2	3	4	1	13.0	2.6	2	3	2	9.6
Infrastructure failure – electricity affecting lifelines and essential services	C	3	High	2	3	3	4	1	13.0	2.6	2	3	2	9.6
Infrastructure failure – telecommunications affecting lifelines or essential services	B	2	High	2	3	3	3	1	12.0	2.4	2	4	1	9.4
Transport accident - marine – passenger	C	3	High	4	2	2	1	2	11.0	2.2	2	3	1	8.2
Transport accident – air crash over populated area	C	4	Extreme	5	3	2	1	1	12.0	2.4	1	3	1	7.4
Transport accident – rail during peak commuter period	C	3	High	4	2	2	3	1	12.0	2.4	1	3	1	7.4
Volcanic - ash from Taranaki eruption	E	2	Low	2	2	2	3	2	11.0	2.2	3	1	1	7.2

4.4 Ratings Tables

The tables below were used to guide the ratings given for each hazard.

4.4.1 Likelihood Rating (How often do these hazards happen)

Level	Descriptor	Description – refer to the maximum likely scenario. (If available, use return periods as a guide)
A	Almost certain	Is expected to occur in most circumstances (0 – 5 year return period)
B	Likely	Will probably occur in most circumstances (0-19 year return period)
C	Possible	Might occur at some time (0 – 99 year return period)
D	Unlikely	Could occur at some time (0 – 999 year return period)
E	Rare	May occur only in exceptional cases (> 1000 year return period)

4.4.2 Consequence Rating

The hazard may not necessarily cause all of the consequences listed in the detailed description. Choose the descriptor that has the most similar consequences.

Level	Descriptor	Detail description
1	Insignificant	No injuries, little or no damage, low financial loss, no measurable environmental impact
2	Minor	First aid treatment, minor building damage, medium financial loss, very short term displacement of people, small short term environmental effects
3	Moderate	Medical treatment required, isolated or single fatality, moderate building and infrastructure damage, high financial loss, emergency resources fully committed, short term displacement of people
4	Major	Extensive injuries, deaths possible, high level of building and infrastructure damage, major financial loss, overwhelms emergency resources, community only partly functioning
5	Catastrophic	Deaths and large number of injuries, large number of buildings extensively damaged and major infrastructure failure, huge financial loss, long term displacement of people, significant permanent environmental damage, all response agencies totally overwhelmed, years of recovery time.

4.4.3 Initial Risk Rating

Choose the rating where the likelihood and consequences intersect.

	Consequences				
Likelihood	Insignificant 1	Minor 2	Moderate 3	Major 4	Catastrophic 5
A Almost certain	H	H	E	E	E
B Likely	M	H	H	E	E
C Possible	L	M	H	E	E
D Unlikely	L	L	M	H	E
E Rare	L	L	M	H	H

4.5 SMUG analysis rating tables

4.5.1 Seriousness

Choose one rating for each column - H E S I G then record the average score. Refer to the descriptions for the consequences given I the tables that follow.

Level	Descriptor	H	E	S	I	G	Ave score
1	Insignificant						
2	Minor						
3	Moderate						
4	Major						
5	Catastrophic						

4.5.2 Human consequences (deaths, injuries, psychological distress)

Level	Descriptor	Detail description
1	Insignificant	Few or no effects
2	Minor	Injuries requiring First aid or no treatment, emotional distress of vulnerable individuals.
3	Moderate	Medical treatment and admissions required, isolated or single fatality, emotional distress
4	Major	Multiple serious injuries requiring medical treatment, deaths, less that 100 people affected. Significant emotional distress and psychological impacts.
5	Catastrophic	Multiple deaths and hospital admissions, Hundreds of people affected, widespread psychological impacts.

4.5.3 **Economic consequences** (direct costs, business loss and interruption, effects on economy)

Level	Descriptor	Detail description
1	Insignificant	Few or no effects
2	Minor	Small number of organisations experience short term loss of ability to trade and generate income
3	Moderate	Loss of ability to trade and income over a period of weeks, moderate direct financial costs or losses. Some small businesses permanently lost
4	Major	Large and or key businesses lost or and reduced ability to trade and income, large direct financial costs or losses. Multiple small business permanently lost.
5	Catastrophic	Long term local, regional and national economic depression. Large number of small and large businesses permanently lost. Significant rebuilding costs.

4.5.4 **Social consequences** (to community networks and facilities, family groups, ability to carry out routine activities)

Level	Descriptor	Detail description
1	Insignificant	Few or no effects
2	Minor	Short term loss of ability to carry out normal community activities. Hours to a few days disruption.
3	Moderate	Dislocation of people from their homes for a period of weeks, short term loss of key community facilities.
4	Major	Permanent loss of key community facilities. Dislocation of up to 100 households.
5	Catastrophic	Complete breakdown of community networks and cohesiveness. Permanent loss of majority of community facilities. Greater than 100 households permanently in need of relocation

4.5.5 **Infrastructure consequences** (lifelines utilities business operations and service provision)

Level	Descriptor	Detail description
1	Insignificant	Few or no effects
2	Minor	Disruption or loss of one lifeline service for a period of hours to a day.
3	Moderate	Business or physical damage to one or more infrastructure systems cause service disruption or intermittent loss of

		service for period of up to one week.
4	Major	Total loss of one lifeline service with effects lasting weeks or simultaneous disruption to multiple infrastructure systems for period of weeks.
5	Catastrophic	Total destruction of multiple infrastructure systems – business and service aspects, total rebuild required.

4.5.6 **Geographic and Environmental consequences** (physical effects on the land and environment)

Level	**Descriptor**	**Detail description**
1	Insignificant	Few or no effects
2	Minor	Short term localised ecological effects requiring clean up or restoration.
3	Moderate	Damage to multiple ecosystems, temporary or localised land form changes
4	Major	Loss of single regionally significant ecosystem, or damage to multiple systems and ecology. Regionally significant and permanent land form changes requiring modified land use.
5	Catastrophic	Permanent loss of multiple ecosystems and irreversible ecological effects, multiple regionally significant land form changes requiring modified land use.

4.6 Manageability

Refer to the maximum likely scenario. Choose the appropriate rating for current effort and management difficulty. Record the score that is in the box where they intersect.

Current effort and management difficulty should be considered across Reduction, Readiness, Response and Recovery, and the average rating allocated.

		Current Effort		
		Low	Med	High
Management Difficulty	Low	4	2	1
	Med	4	3	2
	High	5	4	3

4.7 Urgency

Refer to the maximum likely scenario. Refer to the likelihood rating made earlier and increase score if there are particular issues that increase the need to manage the hazard in the short term.

Ranking	Score	Descriptor
A	5	Almost certain. Immediate, urgent action required
B	4	Likely. Long term heightened urgency level
C	3	Possible. Short term, possible or temporary urgency
D	2	Unlikely. Urgency unknown or negligible.
E	1	Rare. No elements of urgency

4.8 Growth

Choose the appropriate rating for event occurrence probability rise and changing community exposure. Choose the score that is in the box where they intersect.

		Changing community exposure		
		Low	Med	High
Event occurrence probability rise	Low/None	1	2	3
	Med	2	3	4
	High	4	4	5