Estimating post-earthquake welfare and sheltering needs following a Wellington earthquake

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ABSTRACT: A future earthquake in the city of Wellington will cause widespread building and infrastructure damage, particularly on soft soils. It is also anticipated that all major transport routes (air, sea, rail and road) out of the region and many within the region will be affected. Such impacts create challenges for the provision of welfare and sheltering in the aftermath of an earthquake. A model framework for calculating evacuation numbers, welfare needs and sheltering requirements is proposed based on a variety of damage and non-damage related factors that contribute to evacuation decision-making. A household's decision on whether to evacuate or shelter in place is based on a range of factors, including those directly related to earthquake damage such as structural damage and lifeline utility function, and factors that relate to household or neighbourhood liveability such as access to resources, social networks, mobility or dependency. Multiple factors that contribute to household welfare needs and evacuation decision-making have been included to recognise that post-earthquake evacuation decisions are not based on damage states of buildings or loss of lifeline utility services alone. This paper applies structural damage components of the model and discusses the framework for the non-structural component. Preliminary evacuee and sheltering numbers are derived these will be further refined on applying the non-structural evacuation factors. The outputs from this model will assist those tasked with planning for readiness, response and recovery for a major Wellington earthquake event.

1 INTRODUCTION

A future earthquake in the city of Wellington will cause widespread building and infrastructure damage, particularly on soft soils. The last earthquake in the region to significantly impact Wellington City occurred in 1855, when the city was in the early stages of development as a coastal trading town (Grapes 2000). The City now has a population of nearly 180,000 people, concentrated in high-rise buildings in the CBD and mostly timber houses in surrounding hillside suburbs. The city is vulnerable to isolation during large earthquake events due to the location of roads, anticipated damage to the airport and to the port (Wellington Region Emergency Management Group 2005, Brabhaharan, 2010). It is also anticipated that all major transport routes (air, sea, rail and road) out of the region and many within the region will be affected. Such impacts create challenges for the provision of welfare and sheltering in the aftermath of an earthquake. This paper attempts a preliminary calculation of potential welfare and sheltering needs.

When considering potential post-earthquake welfare needs for Wellington, local and overseas examples of mass sheltering and welfare provision are examined to provide context and/or calibration. Recent events in Christchurch, New Zealand, can give some indication of welfare requirements and how many people can be expected to need some welfare assistance. However, it is important to note that Christchurch had many advantages that Wellington is likely not to have, such as a vast road network that was generally undamaged, and an airport that was functional in less than six hours after the February 22, 2011 event. The airport was used as a major evacuation and response hub. The airport added more than 1500 flights during the week after the earthquake (Airways Annual Report, 2011). Given these advantages in the response, Christchurch can give a reasonable indicator of what might be needed in a best case scenario for Wellington.

Overseas events have also shown the range of welfare measures that will need to be managed. For example: following the 1989 Loma Prieta earthquake, there were more than 4,000 landslides effecting the transportation structures and underground pipelines. Due to the geographical isolation of many communities, welfare centres were not set up for almost a week. Citizens created their own welfare centres which included pitching tents in common areas and sharing food (Bolin and Stanford, B47, 1993). Following Hurricane Katrina, damage was so extensive in urban areas that the welfare centres remained open for almost 14 weeks after the initial event. This was, in part, due to Hurricane Rita, which occurred one month later, but also highlights the expectation that secondary events will occur, like aftershocks, after the primary event (Colten et al, 2008).

These previous events have provided important lessons for expanding our understanding of what will be required when a large earthquake occurs in Wellington, New Zealand.

2 EVACUATION AND SHELTERING NEEDS FRAMEWORK

An evacuation and sheltering needs framework has been developed by Wright and Johnston (2010) based on the Californian model of Chang et al (2009). Multiple factors that contribute to household evacuation decision-making have been included to recognise that post-earthquake evacuation decisions are not based on damage states of buildings or loss of lifeline utility services alone. A household’s decision on whether to evacuate or shelter in place is based on a range of factors, including those directly related to earthquake damage such as structural damage and lifeline utility function, and factors that relate to household or neighbourhood liveability such as access to resources, social networks, mobility or dependency. Multiple factors that contribute to household welfare needs and evacuation decision-making are included in the model. This paper discusses the structural and loss of utility service factors that are the first steps in running the welfare and sheltering needs model for Wellington.

2.1 *Estimating Wellington numbers: Rules for determining evacuation percentages based on damage ratio (Wellington)*

One of the factors behind a decision about whether or not to evacuate is the habitability of a residence, with both structure and function being important. Structure refers to the physical state of a building; for example, is it so badly damaged that it is no longer safe (or perceived to be safe, where no official assessment is available) to occupy? "Function" describes whether or not the building is fit for purpose, and depends primarily on the supply of essential services to the building, whether they be normal reticulated supplies or emergency alternatives. Water is particularly important because it is essential for human survival, hygiene and general health. This is of concern for Wellington following a large earthquake close to the city because restoration of bulk water supply to the city could take weeks to months (Beban et al 2012, Cousins et al 2009, 2010), and it is by no means clear that alternative supplies of emergency water will be adequate (Beban et al 2012).

Some types of residence are more vulnerable than others to loss of the normal reticulated services of water supply, wastewater removal, and power. Apartments in particular are critically dependent on reticulated services (especially electricity) because they have few alternatives. In apartments, the electricity supply supports air conditioning, water supply, lighting, heating, elevators, and waste water disposal. Residential properties on sections are less of a problem (a) because the land around them makes on-site disposal of human wastes possible, (b) collection of rainwater is a realistic option, (c) they are nearly all low-rise and so are not dependent on power to run lifts, and (d) are typically expected to have more stored food than apartments.

Also important is the scale of the event. We can realistically expect a few heavily-damaged houses to be repaired within months. A few tens of thousands houses on the other hand, as has become apparent in the recent Christchurch Earthquake, might take years to repair. Thus, modelling the chain of decisions required in the habitability decision needs to include at least the following steps:

1. Was it a major earthquake (i.e. magnitude >= 7.0)?

2. Was the site in the epicentral region (i.e. MMI >= 9.0)?

3. How many buildings (or people) were affected (1000, 10,000, or 100,000+)?

4. What was the damage state of the building?

5. Was the building an apartment (i.e. more than 3 storeys)?

Our procedure was: (a) to create an earthquake scenario (e.g. a magnitude 7.5 event located on the Wellington Fault); (b) to estimate the shaking intensity pattern over Wellington City using the MMI (modified Mercalli intensity) attenuation model of Dowrick & Rhoades (2005); (c) to estimate the damage state of each building in the city using fragility functions that linked the shaking intensity with expected levels of damage in various types of building

(Cousins et al 2008, Cousins 2010); and then (d) to decide how long each building would be uninhabitable. Table 1 describes potential damage states of a building, and also the expected impacts of the damage states on the habitability of the building. The damage states described are the qualitative classes used for this model and in the RiskScape modelling software (King et al, 2008).

Table 1 Definitions of building damage states, and habitability status of buildings in each of the various states.

Damage State	Definitions	Consequences
5. Collapse	Building has to be rebuilt, deaths and serious injuries likely	Uninhabitable until rebuilt
4. Severe	Building did not collapse, but is so badly damaged that it needs to be rebuilt	Uninhabitable until rebuilt
3. Moderate	Considerable structural damage, but repairable	Uninhabitable until repaired
2. Light	Mostly non-structural (cosmetic) damage that needs to be repaired	Possibly uninhabitable whilst repairs are being done
1. Negligible	Not more than cosmetic damage	Habitable at all times

The period that a building will be uninhabitable after a major earthquake could depend on many factors, including:

- the level of damage to the building itself, and to the other buildings in the region (as dangerous buildings can render adjacent buildings unsafe for use),
- the time needed to plan the re-construction process, and to assemble contractors and resources (including insurance inputs),
- the availability of critical lifelines that supply water, food, fuel, power, and communications.

Some of the time estimates are broad, but the reality is that there will be a great deal of variation from one suburb to another (e.g. for restoration of bulk water, road access); there will be some overlap (for instance the bulk water is likely to be restored during the planning hiatus and so will not be the main time determinant for heavily damaged buildings); and there will not be enough resources for all buildings to repaired at the same time (we assume that the earliest start time is at the end of the planning period, and that the last repairs will start 12 months after that). Another factor to be considered is that stored water will be available for emergency use for about one to two weeks after the earthquake, assuming a consumption rate of 20 l/p/d (litres per person per day) and that about half of the water in reservoirs remains in the reservoirs after the earthquake (Beban et al, 2012).

Table 2 Broad estimates of the times needed for various phases of work that are expected to control the repair and reconstruction of residential buildings following a Wellington Fault Earthquake. Estimates based on RiskScape modelling and sourced from Wright et al (in prep).

Damage State	Planning Hiatus (months from event)	Bulk Water Outage (months from event)	Building Repair Start (months from event)	Repair Duration (months)	Uninhabitable Period (months from event)
Collapse	6	1 – 3	6 – 18	6 – 12	12 – 30
Severe	6	1 – 3	6 – 18	6 – 12	12 – 30
Moderate	3	1 – 3	3 – 12	3 – 6	6 – 18
Light	1	1 – 3	1 – 6	1	0 – 3
Negligible	0 – 1	1 – 3	0 – 3	0.25	0 – 3

3 MODELLING RESULTS

In order to estimate the damage status of buildings in Wellington City we used RiskScape, a multi hazard risk-modelling tool being developed by GNS and NIWA (National Institute of Water and Atmosphere) (King et al 2008). One of the key outputs of RiskScape is the damage state of a building. Running the model for a magnitude 7.5 Wellington Fault Earthquake impacting Wellington City gave the results listed in Tables 3 and 4. Apartments were defined as accommodation buildings larger than 500 m2 (assumed to be multi-living unit), and houses as accommodation buildings smaller than 500 m2 (assumed to be single unit). Approximately 22 apartment buildings and 2000 houses were designated as uninhabitable and needing to be rebuilt (i.e. were in damage states Collapse or Irreparable). Following the times given in Table 3, the nearly 5000 people in those buildings could expect to be displaced for 12 – 30 months (Table 4). A further 100 apartments and 11,000 houses would suffer structural damage sufficient to make them uninhabitable for 6 to 18 months after the earthquake, affecting 28,000 people, while the remaining 470 apartments and 56,000 houses, homes to about 140,000 people, could be uninhabitable for up to 3 months, depending largely on the access to emergency water and other necessities of life.

Table 3 Impacts of a Wellington Fault Earthquake on Wellington City – numbers of apartments and houses in various damage states, and numbers of people affected. (Numbers have been rounded to 2-3 significant figures.)

Building Damage State	Number of Buildings		Number of People	
	Apartments	Houses	Apartments	Houses
Collapse	7	460	180	1,100
Severe	15	1,500	350	3,500
Moderate	100	11,000	2,200	25,300
Light	150	21,000	3,300	49,000
Negligible	320	35,000	7,500	80,000
Totals	600	69,000	13,600	159,000

Table 4 Impacts of a Wellington Fault Earthquake on Wellington City – displacement of people from their homes. (Numbers have been rounded to 2-3 significant figures.)

Displacement Time (months)	**Numbers of People Displaced**
12 – 30	5,000
9 – 18	28,000
0 – 3	140,000
Total Number	172,000

The above discussion relies heavily on judgement that is based on preliminary data from the Darfield and subsequent earthquakes. Modelling of the loss and restoration of water for Wellington is also broad-brush and stands to be updated by more detailed suburb-by-suburb modelling that describes both bulk and reticulated water supplies.

If it is a major earthquake and a home is within the epicentral region, then we assume that bulk water supply will be lost for 1 month. Apartments (identified here as buildings more than three storeys high) are treated more severely than houses, because apartments are likely to be totally uninhabitable if any one of water supply, sewage system, or power supply is lost. This distinction applies only to buildings in damage states 0 or 1 because those in higher damage states will be uninhabitable for 1 or more months anyway due to the time taken to repair the damage.

4 CONCLUSIONS

Limited transportation options coupled with expected widespread damage and disruption to services means many people may have to shelter in place or be looked after in welfare centres following a Wellington earthquake.

With 140,000 people potentially without homes for more than 3 months, planning for adequate provision of welfare will be critical to a successful response and recovery. With these high numbers, it means there is likely to be a greater reliance on public and non-governmental organisations to provide the welfare needs of people in Wellington than has been seen previously in any other emergency in New Zealand’s history. It is also important to understand that the need for welfare provision is likely to last for weeks to months, rather than days, due to the extensive damage of homes and apartment buildings. These calculations will be further refined on consideration of non-structural and non-functional factors such as neighbourhood liveability and household demographics.

This information is critical to ensuring adequate provision of welfare for those affected by the Wellington earthquake. Without adequate planning for this scenario, the cost in potential loss of life and human suffering will be much higher than is acceptable.

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