CHRISTCHURCH MULTI-HAZARD ANALYSIS APPROACH

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ABSTRACT

Christchurch is a low-lying coastal city subject to a large number of natural hazards. These hazards affect different locations across the city with varying frequencies and magnitudes. Large parts of the city are subject to multiple hazards, including areas adjacent to lower river reaches and the coast. These areas were significantly impacted by the Canterbury Earthquake Sequence ('the earthquakes'), which began in September 2010, and produced a cascade of geomorphic, built and human environment changes that altered the profiles of several other hazards.

Anthropogenic climate change or disruption is forecast to have pronounced effects on Christchurch city. The most notable include flooding-related hazards: coastal, fluvial, pluvial and groundwater. Unlike event-based hazards, climate disruption is a chronic stressor, with its general occurrence over the foreseeable future now largely certain. The premise is that decisions regarding long-term planning and immediate infrastructure repair and remediation can be more effective at enhancing the city's resilience if they are made in the context of the multiple risks associated with the full range of natural hazards the city is subject to.

A multi-hazard assessment approach for long-term planning is being undertaken in Christchurch to inform Christchurch City Council's ('Council') decision-making on future infrastructure planning and construction. Whilst ultimately focused on responding to fluvial and pluvial flooding, historically the most frequent hazard for this city, the approach considers a range of hazards holistically, through a 'multi-hazard' lens. This promotes effective, long-term sustainable interventions to reduce risk. The approach is being used to answer the question: *How do we make decisions about flood management in a multi-hazard environment?* A multi-hazard assessment of flood response options, including various defences, will help inform decision making on the most appropriate way to manage the city's floodplains now and in the future.

In this assessment the following natural hazards have been considered: fluvial, pluvial, groundwater and coastal flooding; earthquakes and their cascading hazards such as liquefaction, subsidence, lateral spread, ground shaking, tsunami; coastal erosion and mass movement. The 'multi-hazard' assessment approach being applied for Council considers the range of hazards which may affect an area and the interrelations that might exist between them. Multi-hazard assessments provide a fuller picture, which can be used to estimate total risk, including likely physical damage, disruption and economic losses. In contrast, traditional single hazard approaches to flooding considers options for management of the individual hazard but can ignore the costs and benefits associated with simultaneously responding to other hazards and hazard interactions. The latter approach can both under- and over-estimate risk, distort management priorities, and/or invoke responses to one hazard which increase vulnerability to another linked hazard, locking councils into considerable extra hazard management costs. In this unfortunate situation councils' original flood management decisions might potentially be called into

question: for example, where a decision was made to defend against a single hazard, subsequent decisions for responding to other hazards might influence the cost of implementing the already planned-for defences. Other possible consequences of a single hazard focus include:

- where actions taken to mitigate the effects of one hazard increase vulnerability and exposure to other hazards such as when construction of stopbanks supports development in areas subject to tsunami risk;
- when the possible efficiencies of developing a response to mitigate two or more hazards (e.g. coastal flooding and tsunami) are missed; or
- where defences against one hazard are found to be unsustainable due to another hazard (e.g. the effect of coastal erosion on flood defences).

The goal of Christchurch city's multi-hazard approach is to develop, and apply, a robust framework to inform future infrastructure and long term planning decisions to reduce flood risk, and benefit current and future generations. The objectives that need to be met to achieve this goal are to:

- develop a sound base of scientific and other information to support hazard identification and evaluation, including quantification of interactions between multi-hazards;
- engage with relevant authorities to understand the drivers for implementing hazard mitigation and long term strategies;
- test a range of hazard scenarios to establish the sensitivity of outcomes resulting from decisions to a range of possible future events;
- develop a decision making framework based upon scenario findings to apply to future infrastructure planning; and
- develop suitable materials and information to present to the public to allow meaningful engagement.

The results of the multi-hazard assessment will be useful for a range of Council roles, functions and responsibilities, including: planning and development, risk reduction decision making, consenting, and Civil Defence Emergency Management (CDEM) readiness and response, and more generally for promoting risk reduction in an efficient and cost effective way through collaborative work programmes.

The advantages of a multi-hazard approach include:

- a fuller understanding of hazard exposure and consequences, providing a better understanding of total risk and greater clarity to the community regarding long term planning and intervention decisions;
- greater transparency and robustness in decision making and less chance of regretting decisions made;
- a reduction in risk to the community from natural hazards;
- improved response capability based on realistic scenarios;

- that planning and development decisions are appropriate for both current and future generations; and

- developing effective, long term and sustainable interventions as a prudent and responsible use of Council funds.

Some hazards are independent of each other while others are highly interrelated and dependent, with potential for interactions and cascading effects between the latter multi-hazards both the short- and long-term. These interactions between the hazards are understood at a conceptual level, and can be grouped under the headings of spatial co-location, temporal coincidence and cascading impacts. These terms are defined as follows:

- *Spatial Co-location* is the possibility of two or more hazards affecting the same spatial location regardless of the frequency of the hazards or the period of time between individual hazard events;

- *Temporal Coincidence* is the possibility that two hazard events can occur at the same time and in the same location. In the context of this study, it is the co-incidence of non-flood hazards with flooding events that is of primary interest.

- *Cascade* refers to the occurrence of one hazard event, followed some time later by a second type of hazard occurrence, whereby the first hazard event has altered some geomorphologic or other condition to such a degree that the manifestation of the second hazard is altered (e.g. exacerbated, lessened or even triggered). In the context of this study, we are interested in when non-flood hazards affect the likelihood or nature of future flooding hazard events.

Examples of these interactions include:

- land damage (e.g. lowering of the ground surface) resulting from future earthquakes could significantly increase future flood risk (fluvial, pluvial, coastal and groundwater);

- sea-level rise is hampering drainage of low-lying areas, thereby increasing flood risk and groundwater levels. Future accelerated rises will likely contribute to an increase in the area susceptible to liquefaction; and

- climate disruption is likely to result in an increase in the intensity of extreme weather events, increasing risks from flooding, coastal inundation and coastal erosion.

The multi-hazard assessment project has been underway for over a year, and so far has significantly improved our quantitative understanding of multi-hazards interactions affecting the city environment. The completed Stage 1 technical report is available on-line - see item 5 at:

http://christchurch.infocouncil.biz/Open/2017/08/CNCL_20170803_AGN_1294_AT.htm .

Key findings of the analyses to date include the following:

- Downstream river and coastal areas of eastern Christchurch are subject to a large number of hazards, with only 20% of the study area unaffected by any

of the mapped hazards. Over 20% of the study area is exposed to four or more hazards according to the available frequency estimates and other data.

- The majority of the area known as the Residential Red Zone (identified following the earthquakes largely based on seismic hazards) is strongly exposed to multiple seismic and non-seismic hazards, with 86% of the area being exposed to 4 or more hazards, and 24% being exposed to 6 or more hazards.

The analysis presents the existing hazard information and maps areas of hazard co-location and co-incidence. It clearly indicates the importance of considering all hazards and their interactions before considering the potential engineering, planning and policy responses to the associated multi-risks.

Although there were a significant number of relevant technical studies available for this project, analysis revealed a number of gaps where additional technical information was required to improve the multi-hazard analysis, and inform the development of floodplain management plans. Seven areas of further work were prioritized, with new studies currently underway into:

- the significance of the co-incidence of fluvial, pluvial and coastal flooding events, and the extreme weather causing these events;
- the significance of elevated groundwater levels to flooding from rainfall run-off/percolation;
- the consideration of more frequent tsunami events than the commonly used 'worse-case scenario';
- the nature and likelihood of additional vertical ground displacements from future earthquakes;
- updating and verifying the coastal sediment budget and its contribution to coastal erosion and accretion (sediment deposition);
- information on the nature, location and value of CCC assets for the economic analysis of the multi-hazard assessment; and
- specific design guidance for CCC infrastructure in floodplains.

The findings of these studies will be summarised and presented at the conference.

The final project stage will analyse the data, consider a range of potential flood management options, as well as develop a decision making framework to identify preferred options and adaptive pathways. The framework will also consider the protection of ecosystems, the integrated management of land and water, and the social and cultural impacts of the intervention options. Options will be considered within this framework to compare costs and benefits, taking into account any uncertainties in the available information, and inform decision making.

In conclusion, effective risk reduction from natural hazards is only possible in Christchurch if all relevant threats are considered. The natural system needs to be considered as a whole in an all-hazards approach. Parts of Christchurch are vulnerable to a level of risk that for some hazards is undesirable and potentially, unacceptable. The multi-hazard assessment described in this paper will contribute significantly to a better

understanding of consequences. The work is, therefore, vitally important to making informed decisions on floodplain management now and into the future. Understanding the risks posed by multi-hazards (including those associated with climate changes) will help Council make better decisions in what constitutes a very large infrastructure programme.

KEYWORDS

Multi-hazard, floodplain management, planning, earthquakes, liquefaction, flooding, coastal erosion and inundation, groundwater