International Journal of Disaster Risk Reduction xxx (xxxx) xxx–xxx

Contents lists available at ScienceDirect

International Journal of Disaster Risk Reduction

journal homepage: www.elsevier.com/locate/ijdrr

Reactions to earthquake hazard: Strengthening commercial buildings and voluntary earthquake safety checks on houses in Wellington, New Zealand

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ARTICLE INFO

Keywords:
Earthquakes
Earthquake prone
Strengthening buildings
Quakechecks
Legislation
Norms

ABSTRACT

Although many countries have legislation requiring strengthening of earthquake prone buildings, there are significant obstacles to retrofitting these buildings to make them more resilient. This research examines actions in regard to earthquake prone commercial and public buildings in Wellington and checks on private homes following the 2010/2011 Canterbury earthquakes and the 2013 Seddon/Cook Strait earthquakes. The study obtained data on commercial and public buildings removed from the Wellington City Council Earthquake-prone Buildings List (EQPB List) from 2012 to 2016 due to various mitigation actions (e.g., demolition and strengthening). The study also obtained rates of self-initiated voluntary Quakecheck home assessments for the same period. Results indicate ongoing removal of significant numbers of buildings from the EQPB List in this period, with strengthening being the most frequent action. This finding suggests that despite real obstacles, various incentives including legislation are leading to consistent earthquake preparation over time, often before the legislative deadline. In contrast with the EQPB data, the Quakecheck data indicate a sharp but short-lived spike after the Seddon / Cook Strait earthquakes. As a marker of self-initiated mitigation action, this brief spike suggests that in the absence of relevant legislation or insurance incentives, citizens' actions are only briefly influenced by the experience of an earthquake. These contrasting findings for EQPBs and Quakechecks suggest the value of legislation to drive mitigation actions for all buildings.

Earthquakes are unpredictable events that occur infrequently in any one location yet can have disastrous consequences. Large damaging earthquakes have occurred recently in several countries, including Japan, Tibet and Haiti. Seismic activity in New Zealand was recently demonstrated by a series of destructive earthquakes in 2010 and 2011 in the Canterbury region, followed by the 2013 Seddon and Cook Strait earthquakes (near the city of Wellington) and the 2016 Kaikoura Earthquake. The February 2011 Christchurch earthquake triggered widespread damage and 185 fatalities [12].

Although earthquakes are uncontrollable, damage in earthquakes can be mitigated. The disaster that occurs in earthquakes is not the hazardous earthquake itself, but rather the damage resulting from inadequate preparation [2]. Preparation can greatly reduce the potential harm from earthquakes [14]. Many preparation programmes emphasize actions to increase survival after an earthquake, such as storing water [19]. However, preparation should also include actions to mitigate damage from earthquakes such as strengthening buildings [24,30].

1. Strengthening buildings and legislation

Strengthening earthquake-vulnerable buildings is a key preventative measure to reduce the harm triggered by earthquakes, as the major cause of fatalities and losses in earthquakes is building collapse [29]. This is most obvious in countries where earthquake legislation is not strongly implemented, such as Nepal, but it also applies in countries with such legislation. For example, fatalities from the 2011 Christchurch earthquake resulted from the collapse of buildings and facades on commercial buildings [23]. Although the majority of fatalities were due to the collapse of two relatively modern commercial buildings, the remainder were caused by collapsed facades and parapets in older unreinforced masonry buildings built before 1976.

Strengthening buildings is beneficial not only to reduce fatalities in an earthquake, but also to reduce economic losses. As illustrated by the $40 billion rebuild cost from the 2011 Christchurch earthquake (more than 20% of GDP), the cost of earthquake recovery is high [45]. Over 150,000 homes were damaged from this earthquake, with 30,000 in-

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https://doi.org/10.1016/j.ijdrr.2017.12.007
Received 13 September 2017; Received in revised form 18 December 2017; Accepted 19 December 2017

curring serious damage [21]. Buildings that met the New Building Standard (Appendix A) fared better than those that did not, confirming that strengthening buildings reduces losses in earthquakes [23].

Robust legislation on the strengthening of buildings vulnerable to earthquakes is therefore vital for successful damage mitigation [29]. When comparing regions that enforce earthquake legislation to those that do not, it is clear that this practice plays a key role in reducing harm in earthquakes [2,28]. Due to a lack of building legislation and/or the failure to enforce legislation, countries like Haiti and Nepal are vulnerable to earthquakes and suffer many fatalities [13,2,29]. In contrast, New Zealand, California, Japan, and Chile all have more robust earthquake legislation that is enforced and as a result, represent some of the world's most earthquake resilient communities [29]. As a result of Japan's robust building codes, most buildings withstood the powerful 2011 Tohuku earthquake, if not the subsequent tsunami [2].

In New Zealand, national legislation requires that commercial and public buildings built before 1976 that do not meet 33% of the New Building Standard are classified as earthquake prone buildings (EQPBs) and must be strengthened or demolished within a fixed time frame (for details, see Appendix A; for examples of buildings affected by the code, see Appendix B and C). Regions in New Zealand are now categorised into low, medium, and high risk (i.e. hazard) zones (Appendix A). In the Canterbury earthquakes, most buildings that met current building standards survived the earthquakes, leading to lower fatalities, although many of these buildings were subsequently demolished due to owners' decisions to claim the insurance rather than repair the buildings [45].

2. Motivations for strengthening buildings

In addition to relevant legislation, there are a number of other reasons why people undertake earthquake prevention measures such as strengthening buildings. Several motivations support the decision to strengthen EQPBs, including economic and psychological reasons. One reason pertains to long-term economic benefits where owners reduce possible economic losses after an earthquake [45]. Building owners may also strengthen earthquake-prone buildings to increase their sale value [31], as commercial buildings classed as earthquake-prone have lower values, particularly in high hazard zones such as Wellington [8]. Even in regions not directly affected by the Canterbury earthquakes, the heightened sense of risk produced by these earthquakes was enough to reduce the market price of some buildings. Timar, Grimes and Fabling [37] found that an official earthquake-prone declaration on commercial buildings in Wellington city following the Christchurch earthquakes lowered the sale price of these buildings.

Awareness of seismic hazard in the property market affects the sales of, and rental income for buildings and the ability to attract and retain tenants [31,5]. Filippova [7] found that many high profile commercial tenants in Auckland (deemed a low risk region) became more concerned about seismic risk following the Canterbury earthquakes. Commercial buildings deemed to be below standard have become less attractive for these reputable tenants, and may be left vacant. Further, these buildings are more difficult to insure, and may have higher insurance premiums. Earthquake strengthening makes these buildings more attractive to these tenants and may also reduce insurance premiums. These factors provides an incentive for owners to undertake earthquake strengthening.

The Wellington City Council offers other incentives for owners to strengthen EQPBs, including a rates reduction when buildings are empty during strengthening and a subsidy for strengthening [43]. Incentives also exist for heritage buildings via The Built Heritage Incentive Fund (BHIF), where grants are given to building owners to assist efforts to strengthen and restore heritage buildings.

There are also psychological reasons why people strengthen buildings, such as to reduce anxiety [22]. Moderate anxiety serves to motivate people to prepare for earthquakes, whereas high anxiety tends to increase denial [12,3,6]. Preparation also reflects the personal experience of an earthquake, which increases concern and preparation [3,27]. For example, citizens in Christchurch prepared more following the Canterbury earthquakes than before [16].

The perceived level of the hazard of earthquakes is also a motivating factor. Citizens in Portland Oregon, supported greater preparation when new seismic reports showed the earthquake hazard was higher than previously believed [9]. New Zealanders see a major earthquake as more likely in Wellington than other large cities [17], with 98% of Wellington residents aware of the risk from earthquakes [12]. Citizens know that Wellington is situated near several fault lines and is classified as a high risk (i.e., hazard) zone for seismic activity ([32,41]). The fact that building codes set a higher standard in Wellington than Christchurch prior to the Christchurch earthquakes reflects this greater perceived risk [44].

3. Barriers to strengthening buildings

Despite these benefits of mitigating actions, many people do not strengthen their EQPBs, reflecting a number of barriers to these actions. Research has examined why some building owners have not adopted earthquake mitigation measures, focusing on building stakeholders [5]. Several factors emerged as impeding owners from adopting mitigation measures.

Firstly, earthquake risk is poorly accounted for in property valuations [5]. These valuations often ignore seismic risks or give varied estimates of the cost of earthquake strengthening. Other barriers include a lack of knowledge or information about seismic risk. Related research examined the regulations for EQBPs following the Canterbury 2010–2011 earthquakes [4]. The authors claimed that mandatory disclosure of a building's seismic risks would highlight these risks and encourage owners to adopt mitigation measures for EQPBs. This recommendation has since been adopted in the 2016 amendment (Appendix A).

Owners of EQPBs also claimed that the short-term cost of strengthening a building is high and would not be recovered in the long term [5]. A key factor is high, non-risk-based insurance premiums, so the significant cost of strengthening may not always lead to lower insurance [5]. Owen and Noy [20] observe that disaster economists have argued for a risk-based insurance regime, as this would allow insurers to lower premiums for properties where owners have taken steps to avoid risk. Egbelakin et al. [5] note that insurers have been reluctant to introduce a fully risk-sensitive regime, as assessments for individual buildings can prove costly and difficult. Despite these barriers and concerns, IAG, one of New Zealand's largest private insurers, has stated that insurance premiums will increase, particularly in high-risk regions such as Wellington [36]. This suggests that insurers may be moving toward a risk-based insurance model, following the experiences of the Canterbury and Kaikoura earthquakes.

Egbelakin et al. [5] also found that building owners said that they might strengthen their buildings if the cost could be recovered through increased rent or property value, but they believed that tenants were unlikely to pay a higher rent for a retrofitted building. Many owners of EQPBs claimed that strengthening their buildings would result in a net loss of revenue. Building owners also claimed that there is little demand for older buildings to have improved performance [5] as buyers prefer newer buildings that are more energy efficient. A further factor is that buildings classed as heritage buildings cannot be demolished or modified without Council permission [10].

Hence, for building owners who have not strengthened their EQBPs, there are a number of obstacles, of which the most important is cost. It is important to note that Egbelakin et al. [5] collected their data before the Canterbury and Cook Strait earthquakes, and some of the views they report may since have changed. Thomas et al. [35] found that rates of strengthening for buildings in Wellington increased markedly immediately following the Canterbury earthquakes. Filippova [7] also

found that tenants and building owners in Auckland were more concerned about earthquake risk following these earthquakes, even though they occurred in a different part of the country. Some building owners were more willing to voluntarily strengthen their buildings to avoid losing reputable and valuable tenants. Thus the immediate cost of strengthening seems less onerous when long term economic costs associated with increased vacancy and tenancy rearrangements are made more salient by a damaging earthquake.

4. The current research

The research cited above shows that although there are significant incentives for strengthening earthquake-prone buildings, there are also major barriers which are preventing progress. So it is important to clarify how much strengthening and demolition is taking place in this context of these conflicting forces. In Wellington, a region identified as a high risk (i.e. hazard) region by the government in 2016, former Heritage New Zealand general manager Ann Neil claimed that five buildings are removed from the Wellington EQPB List of commercial/public buildings each month [34], due to strengthening or demolition. This would suggest solid progress. However, there is little research on whether this reported rate is accurate over an extended period. The research here examines the rate of reduction in earthquake prone buildings (EQPBs) over several years and the reasons for this reduction.

The current study aims to extend previous research comparing building consents to remediate EQPBs in Wellington immediately following the Canterbury earthquakes (2011/2012) with the four years prior ([35]; See also [7,37]). Other research showed significant progress in strengthening heritage buildings in Wellington from 2012 to 2016 [10]. The current study aims to extend this previous research to clarify the nature and timing of strengthening and demolition work on EQPBs in Wellington from 2012 to 2016. To examine this data over this period, the study obtained WCC data that includes the date when the work was completed and the reason for removal from the WCC list (strengthening, chimney removal, demolition, or new information). The study examined the timing of this work following the Christchurch 2010–2011 earthquake sequence and the Seddon and Cook Strait 2013 earthquakes, hereafter referred to as the Cook Strait earthquakes.

A second aim of the study was to examine whether requests by Wellington citizens to have their homes assessed for their earthquake resilience related to the timing of the Cook Strait 2013 earthquakes. Quakecheck home assessments are voluntary and serve as a quantifiable measure of people's self-initiated actions on earthquake preparation, particularly mitigation actions. The study aimed to clarify any pattern in these requests over time and see whether it changed following the 2013 Cook Strait earthquakes. It was expected that there would be a sharp rise in Quakecheck requests after the Cook Strait earthquakes followed by a gradual decline.

5. Method

5.1. Procedure

The authors contacted Hayley Moselen, Team Leader of Seismic Assessments at the WCC, and obtained the data on EQPB and Quakechecks. The authors then met with Moselen to clarify WCC policies regarding EQPBs in Wellington and the processes involved in removing buildings from the EQP Buildings List.

The study used the EQPB List on the WCC website which is updated periodically. The authors also obtained the WCC list of buildings that has been removed from the EQPB List between 2012 and 2016 from Moselen and recorded the date when each building was removed from the list. The date of removal from the list could be up to a month following completion of the work, reflecting the time required for full assessment and processing. WCC also supplied the reasons for the buildings being removed from the list: strengthening, chimney removal, demolition, and further information. Further information refers to new information showing that the building complies with the legislation as a result of further engineering structural assessments.

The authors also obtained WCC records of the number of completed Quakechecks in each quarter in the same four-year period from 2012 to 2016. The assessment uses a checklist that takes 30–120 min to complete and costs $160, a sum that is subsidised by WCC. The Quakecheck programme was developed by the WCC for house assessments and launched in September 2012 [40]. The service is performed either by Registered Master Builders or New Zealand Certified Builders, both of whom have completed a full apprenticeship and training in building. In order to become members of these associations (RMB or NZCB), builders should also meet additional trades qualification criteria, which are set by RMB and NZCB respectively. These builders, on behalf of the WCC, assess whether houses require earthquake strengthening.

Quakechecks (subsequently renamed as Home Earthquake Assessments) use a checklist system and assess the following features of houses which are commonly damaged in an earthquake: the tiebacks on the hot water cylinder; if the house has a header water tank in the ceiling or on the roof, how the tank is secured; the stability and safety of any chimney; the stability of the piles underneath the house and whether the floor bearers are correctly fastened to the piles; the foundations; the connections of the floor joists to bearers; the wall bracing, the wire fixing roof tiles to tile battens (if the house has a clay or cement tile roofs). Quakechecks also include less crucial factors. While tenants may ask that their landlord request a quake check, landlords are not obliged to do so. Quakechecks reports are currently confidential to the house owner because they could affect the value of the house and this would deter voluntary participation. However, licensed real estate agents are obliged, under the Real Estate Agents Act, to report information of material importance to prospective buyers [18]. If an agent is aware of issues brought to light by a Quakecheck, they ought to disclose that information.

6. Results

6.1. Reductions in earthquake-prone buildings

Table 1 shows the numbers of buildings removed from the EQP Buildings List between September 2012 and July 2016 due to strengthening, chimney removal, demolition, and further information showing that the building complies with the legislation. The number of buildings subject to this legislation in Wellington is approximately 5300, of which approximately 750 were classified as earthquake prone in 2015 [38]. The total number of buildings removed from the List in the period from 2012 to 2016 is 204, showing that approximately 50 buildings came off the EQPB List each year.

The number of buildings removed from the EQP Buildings List is presented in Figs. 1 and 2, which show the frequencies for chimney removal, demolition or strengthening over this time period. The 'further information' data are not reported in these figures because this research focused on mitigation actions such as the strengthening of buildings. Fig. 1 displays annual frequencies from 2012 to 2016 to reveal the

Table 1
Buildings removed from WCC EQP Buildings List from September 2012–July 2016 for each of four reasons.

Year	Chimney Removed	Demolished	Strengthened	Further Information	Total
2012	6	1	5	3	15
2013	8	4	29	14	55
2014	1	12	29	19	61
2015	1	6	41	8	56
2016	0	1	10	6	17
Total	16	24	114	50	204

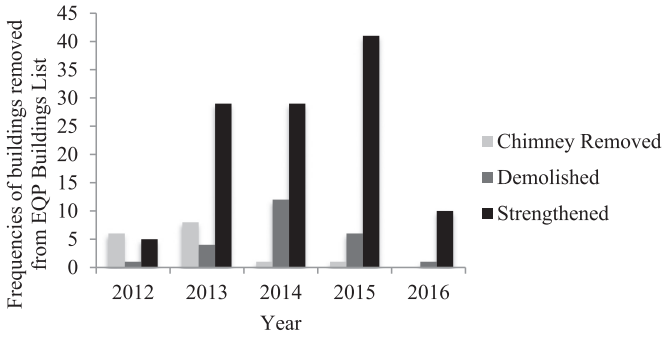

Fig. 1. Annual frequencies of commercial/public buildings removed from the EQP Buildings List, from years 2012–2016, due to chimney removal, demolition, or strengthening. Data for 2012 and 2016 are for six months only.

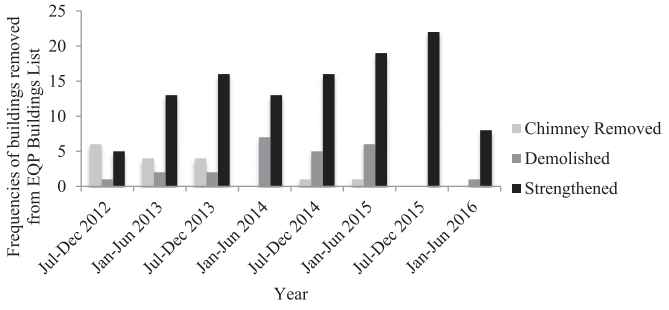

Fig. 2. Six monthly frequencies of commercial/public buildings removed from the EQP Buildings List, due to chimney removal, demolition, or strengthening.

general trend, whereas Fig. 2 gives a more detailed breakdown of six monthly frequencies as the available data begins half way through 2012 and ends half way through 2016. Chi Square analyses compared the four reasons for removal from the list for each year where there was a full data set (2013, 2014, 2015). These analyses indicate that there was no difference between year 2013 and 2014 in the reasons for removal from the list, χ^2 (2, N = 83) = 4.3, ns. However, there was a significant difference between 2013 and in 2015 in the frequencies of the four reasons for removal, χ^2 (2, N = 89) = 13.28, p < .01, and between 2014 and 2015 in these reasons for removal, χ^2 (2, N = 90) = 7.38, p < .05. The specific differences in these frequencies are that there were more chimney removals in 2013 than in 2014 and 2015 whereas there was more strengthening in 2014 and 2015 than in 2013.

Since these data were collated, the EQPB List was further updated. A more recent version of the list in October 2016 states that the number of commercial EQPBs in Wellington reduced to 647. This reduction in EQPBs corresponds to a yearly average of around 50 buildings removed from this List. If this rate was maintained each year from 2017, after 13 years there would be no commercial/public EQPBs in Wellington. This progress is despite the fact that approximately 20% of the buildings on the EQPB list are heritage buildings that cannot be demolished and which can be expensive to strengthen. For example, in 2016, of the total of 647 EQPBs, 127 were heritage buildings. But significant progress is being made on these heritage buildings [10].

The most recent list of EQPBs in Wellington in July 2017, however, indicates an increase in EQPBs, with the number rising to 717. This increase can be attributed to the Buildings [1] Amendment Act 2016, which is government legislation that was implemented from 1 July 2017 and led to changes in the classification of some buildings including being able to classify parts of buildings as earthquake prone, not just whole buildings (See Appendix A). A second piece of new legislation is the Hurunui/Kaikōura Earthquakes Recovery (Unreinforced Masonry Buildings) Order 2017, which allows local governments to require building owners to secure, within one year,

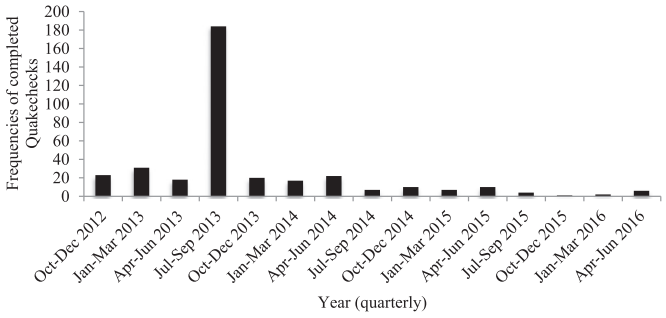

Fig. 3. Frequencies of Quakechecks in domestic houses displayed in quarterly intervals.

unreinforced masonry parapets or facades that may pose a risk in the event of an earthquake (See Appendix A). While the new legislation led to an increase in the number of Wellington buildings classified as earthquake-prone, Moselen reports that "In the past year alone, we have seen approximately 90 buildings resolved as not earthquake-prone via strengthening works, demolition, chimney removal or by providing further structural information" (Moselen, personal communication, 23.8.2017). So despite this one-off re-classification of some buildings as earthquake-prone due to the new legislation, there continues to be large numbers of buildings having their earthquake-prone status remedied. A map of the subsoil classes in Wellington CBD is shown in Fig. 4.

7. Quakechecks

The data reporting Quakecheck assessments ran from September 2012 to June 2016. A total of 362 Quakechecks were completed. As displayed in Fig. 3, Quakechecks spiked in the third quarter of 2013, with 184 Quakechecks in this quarter. This quarter immediately followed the 2013 Cook Strait earthquakes near Wellington. Quakechecks then dropped equally sharply in the following quarters.

8. Discussion

8.1. Reductions in earthquake prone buildings

The data on buildings removed from the WCC EQPBs List suggests that the Earthquake-Prone Buildings Policy and other motives led to ongoing action to reduce the number of earthquake prone commercial/public buildings between 2012 and 2016. The data show an average of just over 50 buildings being removed from the list each year, due primarily to strengthening but also chimney removal, demolition, or further information indicating compliance. The data suggest that work is being performed on many EQPBs prior to Council appointed deadlines for each building, which mostly range from 2022 to 2032. This strengthening of EQPBs is not limited to the Wellington region; the legislation applies nationally and a number of other regions have made good progress in remedying buildings [39,7].

This trend has occurred despite significant obstacles. As pointed out by Egbelakin et al. [5], there are major barriers to remedial work on EQPBs, with economic disincentives being the main impediment. The results here suggest that these barriers are not impeding significant remedial action in Wellington since the Canterbury and Cook Strait earthquakes. The data reported here demonstrate that legislation and commercial motives are increasing Wellington's earthquake resilience. Given the considerable obstacles noted by Egbelakin et al. [5], this finding suggests that the experience of the Canterbury and Cook Strait earthquakes have also prompted ongoing remedial actions [35].

The finding that remedial action often occurred well before the 15-year deadline for a 'high seismic risk' zone imposed by legislation suggests an emerging norm where many owners see this risk mitigation measure as necessary, despite the real barriers [15]. This view is

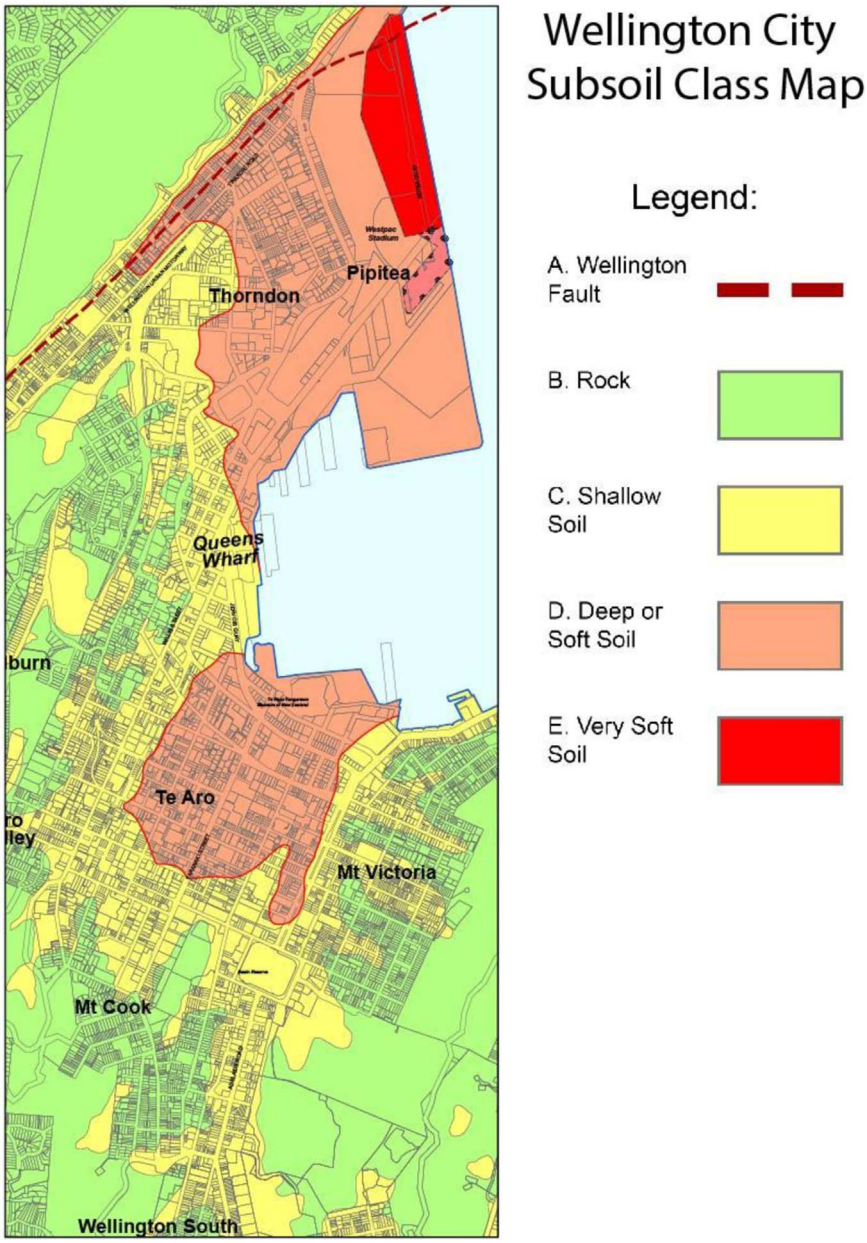

Fig. 4. Subsoil classes for Central Wellington. Adapted from [26].

reinforced by many buildings being strengthened to well above than the required 34% of the New Building Standard (NBS) e.g., buildings brought up to 100% of NBS at additional cost [35]. As the number of resilient buildings increases and the number of earthquake prone buildings reduces, this trend should add normative pressure on remaining owners of EQPBs to take appropriate action and possibly strengthen buildings beyond the minimum required by legislation.

The specific type of mitigation action completed reflects the WCC's seismic assessments, rather than building owners' preferences. Chimney removals occurred most frequently during 2012–2013 and decreased after this period. It is possible that in 2012–13, the WCC were aware of the high number of damaged or collapsed chimneys from the 2010–11 Canterbury earthquakes. The reduction in chimney removals after 2013 may be because WCC assessments apply mostly to commercial or public buildings, few of which have brick chimneys. Building demolitions occurred throughout the 2012–2016 period and were more frequent than chimney removals but lower than mitigation actions such as strengthening. Demolitions peaked in 2014, a year after the Cook Strait earthquakes. From 2013–2016, the strengthening of buildings was more frequent than the other mitigation actions, suggesting that this action became the leading strategy for dealing with these buildings.

8.2. *Self-initiated earthquake mitigation actions: QuakeChecks*

The Quakechecks data indicate a sharp spike in July to September 2013, aligning with the 2013 Cook Strait earthquakes. This spike is high but brief, as Quakechecks rapidly returned to the baseline level in October–December 2013. Unlike actions to remediate earthquake prone commercial / public buildings that are partly driven by legislation and market forces, the Quakecheck data serve as a measure of self-initiated actions. The spike in Quakechecks for a short period following the two Cook Strait earthquakes in 2013 suggests that Wellington citizens had a short-lived burst in concern about the safety of their homes during this time. The low level of Quakechecks before and after this spike is reflected in an article in July 2013 (immediately before the Cook Strait earthquakes) which suggested that the Quakecheck service had a

"lacklustre uptake" since its launch in 2012 ([33], p. 1).

The reactive spike in Quakechecks following the 2013 Cook Strait earthquakes concurs with findings that the combination of the Canterbury 2010/2011 and Cook Strait 2013 earthquakes affected New Zealanders' risk judgments and preparation [15]. For Wellington citizens, this combined sequence of earthquakes strongly impacted risk perceptions, where participants judged a future earthquake as more likely and made more preparations. Mitigation actions were higher in the cities that experienced these earthquakes (Christchurch and Wellington) than in a city that did not (Palmerston North). The Quakecheck data here suggest that increased risk perceptions transferred to mitigation actions, but only in the very short term for most citizens. Quakechecks dropped away more sharply than might be expected. There is no guarantee that Quakechecks led to mitigation actions, although other data indicate that people made more preparations following the Cook Strait earthquakes, which is when Quakechecks spiked [15].

Russell et al. [24] report similar findings in Los Angeles and San Francisco after the succession of two earthquakes, one near Los Angeles and the other near San Francisco. The combination of the two earthquakes led to more frequent recurrent thoughts about earthquakes and more preparation. This result parallels the spike in Quakechecks following the Canterbury and Cook Strait earthquakes. The self-initiated Quakechecks appear to be reactive and limited to the recent experience of a significant earthquake. For use of this service to increase, there may need to be incentives. For example, insurance companies and house sales companies could encourage or require use of this service, possibly as a component in builders' reports on houses which buyers often obtain.

8.3. Limitations and future research

The data on buildings removed from the EQPB List do not represent owner preferences, as each mitigation action (e.g., strengthening) reflects City Council assessment rather than owner concerns. However, what can be interpreted as owners' preferences is when the mitigation actions are completed ahead of the council deadline or when buildings are strengthened to well above the required 34% of New Building Standard (NBS) [35].

A limitation in the data on Quakechecks is the lack of information on the advertising of this service. There may have been increased advertising of the service after the Cook Strait earthquakes that may have led to the spike in use of the service. It is also unknown how many houses failed the checks. However, the data on the take-up of this service is useful for examining patterns in self-initiated mitigation actions, even if causal factors cannot be determined with certainty.

8.4. Implications and applications

There has been much discussion of the large number of EQPB buildings in New Zealand and the barriers to rectifying these buildings. However, WCC records demonstrating the continuous removal of buildings from the EQP Buildings List since 2012 suggest that the relevant legislation and other factors are resulting in ongoing action to increase earthquake resilience of commercial and public buildings in Wellington, thus increasing the likelihood that these buildings will withstand future earthquakes. Citizens' concerns about EQPBs and their positive reactions to strengthening are congruent with these WCC data. The findings suggest that a norm for dealing with EQP buildings is emerging in tandem with the relevant legislation.

Currently, the legislation on EQPBs does not extend to private buildings unless they have three or more apartments. The findings here on Quakechecks would support more robust building legislation to achieve more earthquake-resilient homes. For example, the proposed 'Warrant of Fitness' for rental houses in New Zealand aims to improve the health safety of rental houses, including assessing ventilation and heating [11]. If this scheme is introduced, it would be beneficial to also require that buildings meet a minimal earthquake resistance standard or at least have had a builder's assessment.

The spike in use of the Quakecheck service in 2013 implies that Wellington citizens do respond to the experience of a major earthquake, but only briefly. Although the 2013 Cook Strait earthquakes did not result in any fatalities, in coming so soon after the Christchurch earthquakes, they served as a wake-up call to spark mitigation action [15]. This short-lived Quakechecks response to the earthquakes is an important finding that could be applied to government strategies. As this spike shows that people do act immediately after an earthquake, legislative bodies could use this window of opportunity to increase earthquake resilience and agencies could advertise services such as chimney removals and assessments of house foundations. They could also apply incentives such as targeted insurance policies after this brief period has passed.

9. Conclusion

Previous research has reported data on EQPBs in Wellington before and immediately after the Canterbury earthquakes. This paper reports data on buildings removed from the EQPB List and the reasons for their removal in the five years following the 2010/2011 Canterbury earthquakes. It is also the first study to report the number of voluntary Quakechecks in this period. These two sets of data showed contrasting trends. For commercial/public buildings, there is ongoing removal of a number of buildings from the EQPB List (averaging 50 per year out of a total around 700), through strengthening, chimney removal, demolition, or further information indicating compliance. Some buildings are being strengthened before the deadline and to levels beyond that required by legislation. In contrast with these EQPB commercial buildings, the pattern of voluntary Quakechecks on private housing after the Cook Strait earthquakes suggests that some citizens were concerned with preparation directly after the earthquakes, but this spike was brief.

The role of EQPB legislation in driving the ongoing actions with earthquake prone commercial / public buildings suggests that it could be beneficial for government to extend legislation to private domestic buildings. Agencies could also incentivise activity directly after earthquakes to build resilience and add incentives to maintain this trend. These principles can be applied to other regions vulnerable to earthquakes and possibly to other hazards such as floods, although such research would need to take account of different cultural, legislative and economic contexts. There are also benefits in social scientists combining insights with earthquake engineers to sharpen understanding of the motivational incentives and barriers to earthquake strengthening (e.g., [5,17]).

Acknowledgements

The authors thank Hayley Moselen at the Wellington City Council (WCC) for explaining the WCC seismic assessment process and assisting access to the WCC data.

Funding

This work was part-supported by the MBIE National Science Challenge on Resilience to Nature's Challenges.

Appendix A

The Wellington Earthquake-Prone Buildings Policy [42] implemented the Building Act 2004 which requires all local councils in New Zealand to implement specific policies regarding EQPBs to increase their capacity to cope with future earthquakes [42]. Policies regarding EQPBs cover how commercial and public buildings constructed prior to 1976 (when new building legislation was introduced) are assessed to determine if they are earthquake-prone, requirements for EQPBs, and deadlines for altering these buildings. The process assesses building seismic performance and generates a percentage score of the New Building Standard (NBS). If this percentage is less than 34%, the building is deemed earthquake-prone and an official Earthquake-Prone Building notice is issued, stating the time-frame for the owner to make alterations (or demolish) so that the building is no longer earthquake-prone. The WCC provides an updated list of EQPBs in Wellington online which is accessible to the public.

Following the 2011 Canterbury earthquake, building legislation in New Zealand has seen several important changes. The 2016 Buildings [1] Amendment Act 2016 introduced changes to the way earthquake prone buildings throughout New Zealand are identified and managed. The 2016 Amendment Act came into force on 1 July 2017, and removed the requirement for Councils to have their own earthquake-prone building policies by creating a single national policy framework. The Act categorises New Zealand into three seismic risk (i.e. hazard) areas and sets time frames for taking action to strengthen or remove earthquake-prone buildings. These different levels of risk (hazard) determine the time frame in which commercial and public buildings must be strengthened, ranging from 15 to 35 years. In high and medium risk areas (such as Wellington), criteria for the designation of certain properties as “priority buildings” are also included, and these must be dealt with in half the time frame for other buildings (i.e. 7.5–17.5 years). The Act also revises the definition of an earthquake-prone building in the original Building Act 2004, to also include *parts* of a building, such as unreinforced masonry parapets and facades (Section 123A). The revision extended the criteria for what might be deemed an earthquake-prone building, resulting in an increase in the number of buildings given this classification in the July 2017 EQPB list. The Act also provides more information for people using commercial buildings such as nationally consistent EQPB notices with ratings for earthquake-prone buildings and a public earthquake-prone buildings register (the EPB register).

A second important piece of legislation is the Hurunui/Kaikōura Earthquakes Recovery (Unreinforced Masonry Buildings) Order 2017, which came into force on 28 February 2017, and is to last only one year. The purpose of this order was to increase the ease with which emergency works could be carried out in the Hurunui and Kaikōura regions following the 2016 Kaikōura earthquake. Emergency powers were also granted to local governments in Wellington, Lower Hutt, Blenheim, Hurunui and Kaikoura allowing them to require building owners to secure, within one year, unreinforced masonry parapets or facades that may pose a risk in the event of an earthquake. The Act also revises the classification of a “dangerous” (but not necessarily earthquake-prone) building, as described in the Building Act 2004, to also include those buildings which have these features. The revised status of these “dangerous buildings” prompted by the order led to an increase in the number of structural assessments requested by local authorities, and a resultant increase in the number of buildings declared to be earthquake-prone.

These legislative changes stem from the experiences of the 2010–2011 Canterbury earthquakes, such as falling unreinforced masonry facades and parapets. [25]

Appendix B. Building classified as earthquake prone in Cuba St, Wellington

Appendix C. Recently strengthened building that was previously classified as earthquake prone in Cuba St, Wellington

References

[1] Building (Earthquake-prone Buildings) Amendment Act No 22 … ⟨www.legislation.govt.nz/act/public/2016/0022/22.0/DLM5616102.html⟩.
[2] K. Crowley, J.R. Elliot, Earthquake disasters and resilience in the global North: lessons from New Zealand and Japan, Geogr. J. 178 (3) (2012) 208–215, http://dx.doi.org/10.1111/j.1475-4959.2011.00453.x.
[3] D. Dooley, R. Catalano, S. Mishra, S. Serxner, Earthquake preparedness: predictors in a community survey, J. Appl. Social. Psychol. 22 (6) (1992) 451–470, http://dx.doi.org/10.1111/j.1559-1816.1992.tb00984.x.
[4] T. Egbelakin, S. Wilkinson, R. Potangaroa, J. Ingham, Improving regulatory frameworks for earthquake risk mitigation, Build. Res. Inf. 41 (6) (2013) 677–689, http://dx.doi.org/10.1080/09613218.2013.819546.
[5] T. Egbelakin, S. Wilkinson, R. Potangaroa, J. Rotimi, Stakeholders' practices: a challenge to earthquake risk mitigation decisions, Int. J. Strateg. Prop. Manag. 19 (4) (2015) 395–408, http://dx.doi.org/10.3846/1648715X.2015.1101029.
[6] J.R. Eiser, A. Bostrom, I. Burton, D.M. Johnston, J. McClure, et al., Risk interpretation and action: a conceptual framework for responses to natural hazards, Int. J. Disaster Risk Reduct. 1 (2012) 5–16, http://dx.doi.org/10.1016/j.ijdrr.2012.05.002.
[7] O. Filippova, Tremors and tenants: the effect of a natural disaster and policy changes on commercial office occupiers in New Zealand, J. Prop. Invest. Financ. 34 (2) (2016) 143–155.
[8] O. Filippova, Y. Xiao, M. Rehm, J. Ingham, Economic effects of regulating the seismic strengthening of older buildings, Build. Res. Inf. (2017) 1–14, http://dx.doi.org/10.1080/09613218.2017.1357318.
[9] J. Flynn, P. Slovic, C.K. Mertz, C. Carlisle, Public support for earthquake risk mitigation in Portland, Oregon, Risk Anal. 19 (2) (1999) 205–216, http://dx.doi.org/10.1111/j.1539-6924.1999.tb00400.x.
[10] L. Henrich, J. McClure, The heritage problem: is current policy on earthquake-prone heritage buildings too costly? Policy Q. 13 (3) (2017) 74–79.
[11] Housing and Health Research Programme (n.d.). *Rental housing warrant of fitness.* Retrieved from ⟨http://www.healthyhousing.org.nz/research/current-research/rental-housing-warrant-of-fitness/⟩.
[12] Johnston, D., Becker, J., McClure, J., Paton, D., McBride, S., Wright, K., Leonard,G.,

Hughes, M. (2013). Community understanding of, and preparedness for,earthquake and tsunami risk in Wellington, New Zealand. In H. Joffe, T.Rossetto, & J. Adams (Eds.), Cities at risk: Living with perils in the 21st century (pp. 131-148). doi: 10.1007/978-94-007-6184-1_8.

[13] M.E. Kahn, The death toll from natural disasters: the role of income, geography, and institutions, Rev. Econ. Stat. 87 (2) (2005) 271–284, http://dx.doi.org/10.1162/0034653053970339.

[14] M.N. Lindell, D.J. Whitney, Correlates of household seismic hazard adjustment adoption, Risk Anal. 20 (2000) 13–25.

[15] J. McClure, L. Henrich, D. Johnston, E.H. Doyle, Are two earthquakes better than one? How earthquakes in two different regions affect risk judgments and preparation in three locations, Int. J. Disaster Risk Reduct. 16 (2016) 192–199, http://dx.doi.org/10.1016/j.ijdrr.2016.03.003.

[16] J. McClure, D. Johnston, L. Henrich, T. Milfont, J. Becker, When a hazard occurs where it is not expected: risk judgements about different regions after the Christchurch earthquakes, Nat. Hazards 75 (1) (2015) 635–652, http://dx.doi.org/10.1007/s11069-014-1338-6.

[17] J. McClure, M.J. Spittal, R. Fischer, A. Charleson, Why do people take fewer damage mitigation actions than survival actions? Other factors outweigh cost, Nat. Hazards Rev. 16 (2) (2015) 1–8.

[18] Ministry of Business, Innovation and Employment, *Buying a house – A checklist to help home buyers make informed decisions*. Retrieved December 13, 2017, from ⟨https://www.building.govt.nz/assets/_generated_pdfs/buying-a-house-295-all.pdf⟩, 2017.

[19] J. Mulilis, T.S. Duval, R. Lippa, The effects of a large destructive local earthquake on earthquake preparedness as assessed by an earthquake preparedness scale, Nat. Hazards 3 (4) (1990) 357–371, http://dx.doi.org/10.1007/BF00124393.

[20] S. Owen, I. Noy, The Unfortunate Regressivity of Public Natural Hazard Insurance: A Quantitative Analysis of a New Zealand Case. *Victoria School of Economics and Finance Working Paper*, 2017.

[21] M. Parker, D. Steenkamp, The economic impact of the Canterbury earthquakes, Reserve Bank N.Z. Bull. 75 (3) (2012) 13–25 (Retrieved from), ⟨http://www.rbnz.govt.nz//media/ReserveBank/Files/Publications/Bulletins/2012/2012sep75-3parkersteenkamp.pdf⟩.

[22] D. Paton, Disaster preparedness: a social-cognitive perspective, Disaster Prev. Manag. 12 (3) (2003) 210–216, http://dx.doi.org/10.1108/09653560310480686.

[23] Royal Commission of Inquiry, Canterb. Earthq. R. Comm. Rep. (2012) (Retrieved from), ⟨http://canterbury.royalcommission.govt.nz/Commission-Reports⟩.

[24] L.A. Russell, J.D. Goltz, L.B. Bourque, Preparedness and hazard mitigation actions before and after two earthquakes, Environ. Behav. 27 (6) (1995) 744–770, http://dx.doi.org/10.1177/0013916595276002.

[25] Scoop, Risky facades parapets must be Secur. 12 Mon.; 50% Subsid. (2017) (Retrieved November 26, 2017, from), ⟨http://wellington.scoop.co.nz/?p=96307⟩.

[26] S. Semmens, N. Perrin, G. Dellow, It's our fault - geological and geotechnical characterisation of the Wellington central business District, GNS Sci. Consult. Report. (2010) 52 (Retrieved December 13, 2017).

[27] C. Solberg, T. Rossetto, H. Joffe, The social psychology of seismic hazard adjustment: re-evaluating the international literature, Nat. Hazards Earth Syst. Sci. 10 (8) (2010) 1663–1677, http://dx.doi.org/10.5194/nhess-10-1663-2010.

[28] R. Spence, Risk and regulation: can improved government action reduce the impacts of natural disasters? Build. Res. Inf. 32 (5) (2004) 391–402, http://dx.doi.org/10.1080/0961321042000221043.

[29] R. Spence, Saving lives in earthquakes: successes and failures in seismic protection since 1960, Bull. Earthq. Eng. 5 (2) (2007) 139–251, http://dx.doi.org/10.1007/s10518-006-9028-8.

[30] M.J. Spittal, J. McClure, R.J. Siegert, F.H. Walkey, Predictors of two types of earthquake preparation: survival activities and mitigation activities, Environ. Behav. 40 (6) (2008) 798–817, http://dx.doi.org/10.1177/0013916507309864.

[31] C.M. Stevens, K.E. Wheeler, Implement. Earthq. prone Build. Policy Build. Act. 2004: Wellingt. City'S. Approach (2008) (Report No. 70). (Retrieved from), ⟨http://www.nzsee.org.nz/db/2008/Paper70.pdf⟩.

[32] The Beehive, Map New risk zones Strength. (2015) (Retrieved from), ⟨https://www.beehive.govt.nz/sites/all/files/Map-of-new-risk-zones-for-strengthening.pdf⟩.

[33] The Dominion Post, Homeown. ignore quake Saf. Scheme (2013) (Retrieved from), ⟨http://www.stuff.co.nz/dominion-post/business/residential-property/8870101/Homeowners-ignore-quake-safety-scheme⟩.

[34] The Dominion Post, Creat. Think. key Herit. Fight. (2014) (Retrieved from), ⟨http://www.stuff.co.nz/dominion-post/news/10662050/Creative-thinking-key-in-heritage-fight⟩.

[35] G. Thomas, M. Hosler, S. Cody, Quantifying seismic strengthening in Wellington's commercial building stock, 2013 New Zealand Society of Earthquake Engineers Conference, Wellington, April *26-28*, 2013.

[36] J. Tibshraeny (n.d.). AG says 'high risk regions' like Wellington to be hit hardest with further insurance premium increases. Retrieved December 13, 2017, from ⟨https://www.interest.co.nz/insurance/89477/iag-says-high-risk-regions-wellington-be-hit-hardest-further-insurance-premium⟩.

[37] L. Timar, A. Grimes, R. Fabling, Before a Fall: Impacts of Earthquake Regulation and Building Codes on the Commercial Building Market. Motu Working Paper 15-19; Motu Economic and Public Policy Research, 2015.

[38] L.J. Vinnell, J. McClure, T.L. Milfont, Do framing messages increase support for earthquake legislation? Disaster Prev. Manag. 26 (2017) 28–40, http://dx.doi.org/10.1108/DPM-06-2016-0127.

[39] Wairarapa Times Age, Quake Strength. Begins. (2016) (Retrieved from), ⟨http://times-age.co.nz/quake-strengthening-begins/⟩.

[40] Wellington City Council. (n.d.-a). *Quakecheck home assessment service.* Retrieved from ⟨http://wellington.govt.nz/services/rates-and-property/earthquake-prone-buildings/strengthen-your-home/quakecheck⟩.

[41] Wellington City Council. (n.d.-b). *Wellington City Council guide: Earthquake prone buildings.* Retrieved from ⟨http://wellington.govt.nz/~/media/services/rates-and-property/earthquake-prone-buildings/files/eq-prone-buildings-guide.pdf⟩.

[42] Wellington City Council, Earthquake-prone buildings policy, (2009) (Retrieved from), ⟨http://wellington.govt.nz/~/media/your-council/plans-policies-and-bylaws/plans-and-policies/a-to-z/earthquakepronebldgs/files/earthquake.pdf?la=en⟩.

[43] Wellington City Council, Incentives to strengthen earthquake-prone buildings, (2016) (Retrieved from), ⟨http://wellington.govt.nz/services/rates-and-property/earthquake-prone-buildings/earthquake-prone-buildings/help-for-earthquake-prone-building-owners/incentives-to-strengthen-earthquake-prone-buildings#buildingEmpty⟩.

[44] Whatson Report, Wellingt. Build. Better equipped quakes. (2012 24), ⟨http://www.whatson.co.nz/announcements/wellington-buildings-better-equiped-for-quakes⟩.

[45] A. Wood, I. Noy, M. Parker, The Canterbury rebuild five years on from the Christchurch earthquake, Reserve Bank N.Z. Bull. 79 (3) (2016) 1–16 (Retrieved from), ⟨http://www.rbnz.govt.nz/-/media/ReserveBank/Files/Publications/Bulletins/2016/2016feb79-3.pdf⟩.