9. ROLE OF GOVERNMENT ENTITIES AND FUTURE FLOOD MANAGEMENT POLICY CONSIDERATIONS

The purpose of this chapter is to understand the impact of the 2010-2011 Canterbury Earthquake Sequence (CES) on subsequent flooding in the Canterbury region through a multi-hazard and government policy framework. The chapter has three parts. The first part presents the relevant government authorities and agencies involved in addressing flood hazards in some way, in particular concerning the potential increased vulnerability to flooding caused by the CES and the recent flooding problems that parts of the region experienced in March and April 2014. The second part is an analysis of the flooding governance and management problem at hand. The final part offers some potential options from a multi-hazard and policy perspective as agencies work toward flood hazard mitigation solutions in the region.

The Canterbury region of New Zealand is vulnerable to a wide range of hazards including earthquakes, flooding, storms and fires (ECAN, 2014). While no single multi-hazard plan controls hazard policy making and implementation in the region, collective actions by government entities do constitute a multi-hazard perspective, especially since the CES.

From a governmental action perspective, any understanding of what is occurring in the Canterbury region resides at the confluence and outcomes of two systems: one of disaster recovery and reconstruction from the CES (as evidenced through physical infrastructure rebuilding, relocating of people and buildings; and addressing people's psychological, physical, spiritual, cultural and social needs); and the other seeking to prevent future natural hazard losses through normal functions of local government (as evidenced through regulatory adjustments and infrastructure investments). These systems are not fixed. They are adapting to the cascading influence of the CES as expressed through the floods of 2014. Therefore decisions taken in 2014 towards recovery and reconstruction are subject to continued adjustments based on the reality of the continually changing landform and governance conditions.[1]

Governance agencies

There are many government entities engaged in hazards related policy work in the Canterbury region. Figure 9-**1** illustrates the direct and indirect relationships among these entities that are further explained later in this section.

[1] For example: the landform conditions in 2014 are subject to continued adjustments based on altered geotechnical conditions and assessments. A storm-water solution formed today should be subject to revision as new geotechnical information arises.

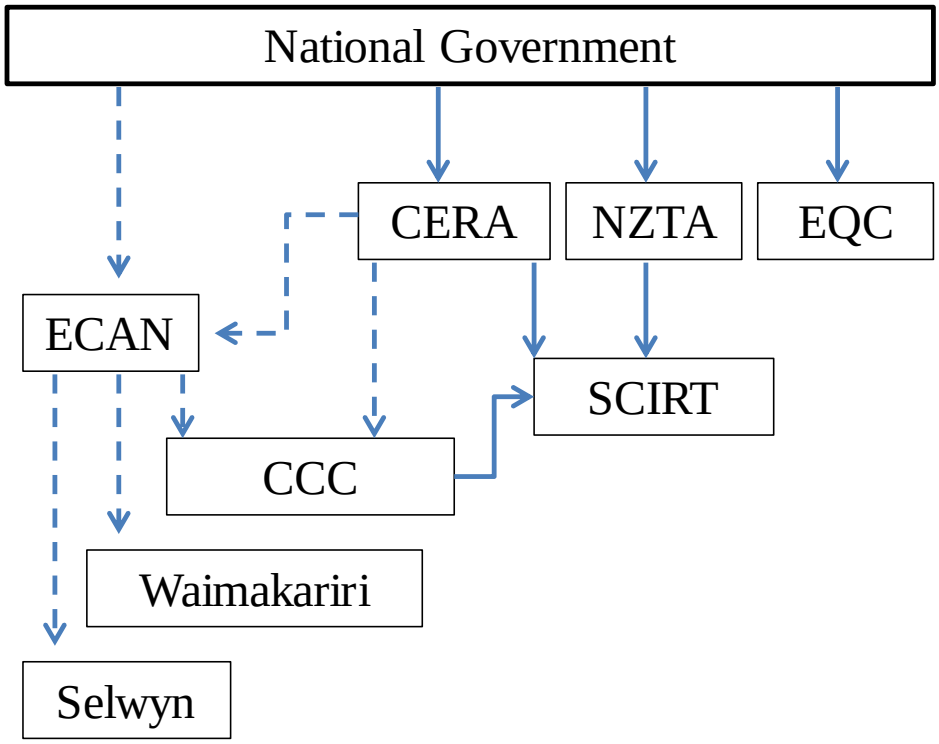

Figure 9-1 Direct and indirect relationships among government entities engaged in hazards related policy in the Canterbury region

The national government (hereafter referred to as "Government") has a direct local presence through the Canterbury Earthquake Recovery Authority (CERA) formed in 2011 to direct the reconstruction phase of the recovery, and the Earthquake Commission (EQC), a crown agency formed in 1993 that insures residential property in New Zealand against natural hazards and is funding major repairs following the CES. The Government also has an indirect presence through the New Zealand Transport Agency (NZTA) that is a major funding agency for road reconstruction following the CES and an owner partner of the Stronger Christchurch Infrastructure Rebuild Team (SCIRT).

The leading regional authority is Environment Canterbury (ECAN), formed in 1989 to manage the region's air, water and land. It implements provisions of the national Resource Management Act (RMA) 1991 (New Zealand Parliament, 1991). One of ECAN's functions as a regional territorial authority is the avoidance or mitigation of natural hazards (RMA 30 (1,C, iv)).

In the metropolitan portion of the Canterbury region there are three district (municipal, local-level) councils: Christchurch City (population 379,000 in 2010) and the districts of Waimakariri (encompassing the towns of Kaiapoi and Rangiora, population 47,600 in 2010), and Selwyn (population 39,600 in 2010) (Statistics New Zealand, 2010). New Zealand does not have states as does Australia or the United States, nor provinces, such as Canada. Thus, the actions of Government directly influence the local government authorities.

Regulatory Framework

The Resource Management Act (RMA 1991) guides environmental management of natural and physical resources, including land use development and permitting processes (New Zealand Parliament, 1991). The Local Government Act (LGA 2002) defines the authorities, responsibilities and powers conferred from Government upon local territorial authorities (New Zealand Parliament, 2002).

The Canterbury Earthquake Recovery Act (CER Act 2011) gives powers to the Government appointed Minister for Canterbury Earthquake Recovery to suspend or make exemptions to almost any New Zealand law including parts of the RMA 1991, and LGA 2002 (New Zealand Parliament, 2011). This legislation will remain in effect at least until 2016 when it is set to expire, at which time CERA would also cease operations in its present form.

ECAN has two major roles related to land use, and flooding and storm water management in the region. The first is through its water management plan. The second role arose via the Earthquake Minister's request in November 2012: in this role ECan has been the lead agency developing the region's Land Use Recovery Plan (adopted December 2013), in collaboration with the NZTA, local councils, and others. The Land Use Recovery Plan is a statutory document, prepared under the CER Act 2011. In this document the Christchurch City Council, Waimakariri and Selwyn District Councils and ECan are directed to make land use changes to district plans, the Canterbury Regional Policy Statement and other instruments in order to accommodate the region wide population growth anticipated in recovery following the CES.

ECAN also develops the region's water management strategy, but the CCC designs, manages, and maintains its own storm-water system under this strategy. The CCC has a statutory obligation under the RMA (1991) to address floodplain management. As recently as January 2011 (just prior to the damaging February 22, 2011 earthquake), the CCC had done so through Operative Variation 48 Management of Flood Hazard in Christchurch (Christchurch City Council, 2011). This specifically identified areas of the city subject to greater risk of flooding than the city generally, and imposed controls on new construction (both the land filling and floor levels for buildings) within those areas.

The District Plan for Christchurch defines the framework for land use and subdivision of land within the district. One of the most important plan chapters is Natural Hazards, where it defines the Flood Management Area (FMA) boundaries (based on Operative Variation 48) and associated regulations for granting various types of consents (permission to build). The District Plan is being updated, and when adopted, the update will have legal status and most likely greater land use controls. The Waimakariri and Selwyn District Councils have similar Natural Hazards chapters in their district plans.

Instruments: Insurance

Insurance generally is used as an instrument for businesses and individuals to transfer risk, and, in turn, to obtain funds for use following a specific type of damaging or injurious event. There are unique aspects of New Zealand's natural disaster insurance system that have a direct impact on the Canterbury earthquake recovery process and issues related to the March 2014 flooding. The Earthquake Commission (EQC) is a Crown entity, established under the Earthquake Commission Act 1993 to provide Government-backed natural disaster insurance for residential property (contents, dwellings and some coverage for land underneath dwellings), against loss or damage from earthquakes, volcanic eruptions, hydrothermal activity, tsunamis, natural disaster fires and natural landslips (New Zealand Parliament, 1993). There are payment limits on EQC coverage so that most residential property owners also obtain 'over-cap' coverage from private market insurers. As compared to most countries in the world, a large portion (80%) of the residential losses in the CES was covered by insurance (Miles et al., 2014). Private market insurers also provide commercial coverage. There is additionally a local authority protection insurance fund to help finance repairs to local public facilities and infrastructure.[2]

It is important to understand New Zealand's unique land insurance coverage. The Earthquake Commission (EQC) Act (1993) specifies that damage caused by the specified natural disasters will be remediated as part of the residential insurance settlement process. The EQC Act specifically covers the land upon which the residential building (and any related outbuildings) are situated; all land within 8 m of the horizontal building line; and some portions of the land underneath the primary access point to the site, such as a driveway. New Zealand may be the only place in the world that provides this coverage; as such coverage is not available in the United States, Canada, Japan, Mexico, China, and Chile to name some countries with high seismic risk. The EQC policies also provide for some limited coverage for land damage caused by storms and floods, but the policyholder must have private insurance to cover flood damage to the residential structure or contents (EQC, 2012).

Increased Flooding Vulnerability (IFV) caused by earthquakes is a type of land damage that can be covered under an EQC policy. The EQC reports that there are 309 properties currently on hold within the Canterbury Home Repair Programme (CHRP) because the property has been identified as potentially having IFV land damage from the CES (EQC, 2014). Modeling is currently underway by the EQC's geotechnical engineers, Tonkin and Taylor, and their May 2014 scheduled report will delineate the extent of flood prone properties impacted by the CES. After this, EQC will advise all affected property owners of the next steps in settling their land claim. The EQC reports that some of the properties fall within the Christchurch City Council's existing flood management areas (FMAs), while other are outside the FMA boundaries. A 2012

[2] In 1993, local authorities created a Local Authority Protection Programme (LAPP) fund and make annual contributions to the fund to meet their 40% share of the costs to restore essential local infrastructure (such as local roads, potable water and wastewater systems, and stop banks) after a natural disaster; New Zealand's Government contributes 60%.

CCC report states that there are 1,268 more properties with a potential to flood within the Avon Styx and Heathcote catchments since the earthquakes (CCC, 2012; 2). The EQC and CCC statements establish a range of possible earthquake associated flood damage categories for properties, but not an absolute number that experienced land damage.

SCIRT

The Stronger Christchurch Infrastructure Rebuild Team (SCIRT) is an alliance formed in 2011 to rebuild damaged street level civic infrastructure—roads, bridges and retaining walls, and potable water, wastewater, and storm water systems—in the Canterbury region damaged by the CES (SCIRT, 2014). The alliance is between three funders (CERA, NZTA and CCC) and five New Zealand construction firms (City Care, Fletcher Construction, Fulton-Hogan, McConnell Dowell and Downer). SCIRT is structured with a Board drawn from the Principals, a management and integrated services team, and five delivery teams, one each from the constructor principals. SCIRT is estimated to spend NZ$2.5 billion before the alliance is dissolved and works are transferred back to NZTA (highways only) and into the CCC administrative structure in December 2016.

SCIRT's earthquake-related repair works that are most relevant to flood hazard management are the storm-water system repairs and repairs to roads and bridges in flood-prone areas. The Alliance Agreement created in 2011 calls for rebuilding infrastructure at least to pre-earthquake standards.[3] In practice, SCIRT's policy has been to repair and rebuild the networks using a 'like for like' approach, except when there is a more modern material or method to use when needed. Under general operational rules, there are no provisions for major upgrades or improvements *per se*, but requests can be made for enhancements by owner partners or promoted by SCIRT for such as network rationalization. The CER Act (2011) does provide statutory language that can allow for this. For example, with respect to storm water management, a set of SCIRT 'network level of service' parameters (i.e. operational cost, effectiveness, resilience and remaining asset life considerations) drives the decisions on what and how to replace various system elements.

CERA

The Canterbury Earthquake Recovery Authority (CERA) is the agency established by the Government to lead and coordinate the ongoing recovery effort following the CES. CERA reports to the Minister for Canterbury Earthquake Recovery, Gerry Brownlee, who is responsible for coordinating the planning, spending, and actual rebuilding work needed for the recovery on behalf of the Government. Special powers have been vested in the Minister for Canterbury Earthquake Recovery and CERA in order to enable an effective, timely and coordinated

[3] This agreement marks the transition from the Infrastructure Recovery Management Organisation (IRMO) repair works to the more comprehensive rebuilding works being undertaken by the Alliance.

rebuilding and recovery effort.[4] CERA is an 'owner participant' partner in SCIRT, and has a voice in the reconstruction of all the horizontal infrastructure networks.

Also, since 2011, the Government, through CERA, has been implementing a buyout of over 7,300 properties in the Christchurch and Waimakariri districts. Collectively termed the "Residential Red Zone" (RRZ), these properties are located on the eastern flat lands area and in the Port Hills suburbs. Much of the RRZ area is near the Ōtākaro/Avon River, which is where water from the Dudley Creek flood area is conveyed, and other tributaries running through the flat lands of Christchurch's eastern suburbs. RRZ areas are defined as having significant and extensive area wide land damage during the CES where the success of engineering solutions may be uncertain in terms of design, and possible commencement, given the ongoing seismic activity, and any repair would be disruptive and protracted for landowners (CERA, 2014a). Given the size of the problem (the number of affected properties, the uncertainty about the cost and time required for repairs, the Government's long term exposure to liability and the on-going seismic risk), Government acquisition became an acceptable alternative strategy to displacing residents for prolonged period of time to complete the recommended area-wide land remediation works (Rogers et al. 2014).

Analysis: Gaps in the present system

Christchurch is facing, and working to address, a long-term problem: flooding (meaning exceeding the capacity of the in-place storm management system to convey water within its boundaries) that has been exacerbated by the CES. There were flood problems before the earthquakes but the land subsidence and other differential settlements caused by the earthquakes have exacerbated the flood hazard management issues in the region. The CCC is working to strengthen its regulatory framework and also considering sea level rise in updates (e.g. Variation 48), and the instruments (technical, i.e. Flood Management Areas, and legal) are understood by staff (Waste Water and District Plan update personnel) who were interviewed. The challenge now is determining the potential frequency of large rainfall or tidal events and severity (i.e. expected damage levels given the present urbanization settlement pattern) and determining what can feasibly be done, and by whom.

Based on field observations and a review of key technical studies (e.g. Tonkin and Taylor, 2013), it is posited that the problem has a series of parts, including:

- improve the conveyance capacity of the present storm water system;
- review the design parameters of current flood models to ensure that they are considering the 'new normal' for flooding impacts post-CES, especially in light of the March and April 2014 experiences;
- consider whether the proposed Flood Management Areas (FMAs) in the draft natural hazards chapter of Christchurch's District Plan are large enough to address future flood risk;

[4] CERA closely coordinates its efforts with the Ministry of Social Development and Housing New Zealand. These agencies do not provide direct hazard related services, and therefore are not included in this section's analysis.

- determine who pays for any proposed changes to infrastructure (i.e. storm water system) or other flood management strategies;
- determine how improvements get made, that is, who does the work of design and construction; and
- determine what policy steps are needed to reach good outcomes.

Possible options to consider

The Canterbury region faces new flood hazard conditions caused by the altered landform of the Canterbury Earthquake Series (CES). If not addressed now, flooding hazards and risks will be magnified, in a continuation of bad outcomes. The organizational framework for an immediate "betterment" approach to storm water is in place in the Canterbury region, benefited in part by the infusion of regulatory (CER Act 2011 Variation 48, CERA Land Use Recovery Plan), technical (major private sector geo-science support), and financial resources (e.g. $NZ 2.5 billion for SCIRT) following the CES.

Based upon this review, six policy options are offered to address the increased flood vulnerability caused by the CES, as well as providing some added long-term benefits to help address the anticipated effects of climate change (i.e. precipitation and sea level rise) and future land use patterns. The first four are more reflective of the status quo and the district councils' traditional lead responsibilities in flood hazard management. The other two look more collaboratively to leverage the resources of governmental arrangements currently working in the region, particularly the CCC (and other district councils depending upon scope), CERA, and the EQC. By collectively pooling and leveraging of resources (particularly RRZ land, EQC claims obligations, and on-going flood and earthquake related works of the CCC and SCIRT), both the current flooding problems and any future flood liabilities caused by known gaps in the region's storm water management system may be more substantially reduced, and in a much more timely and effective way.

1. Improve the overall maintenance and repair of the current system to assure maximum conveyance of the existing system. This might include reducing obstructions such as residential bridges over drainage ways. The responsibility of this task lies mainly with the CCC and other district councils.

2. Undertake more locally focused incremental improvements. In March 2014, the Christchurch City Council received an engineering report (Jacobs, 2014) that offered two options for addressing post-earthquake flooding in the Flockton area of the Dudley Creek catchment. Option 1 proposed channel and culvert upgrades that are projected to protect 550 properties at a cost of NZ $50 million. Option 2 proposes a pump station and channel upgrades that are projected to protect 490 properties at a cost of NZ$ 53 million. Option 1 requires channel widening within the Residential Red Zone, while Option 2 does not. Thus, Option 1 may require easements and conditions of use granted by the Government and other affected property owners. These options are based upon projected 50-year annualized rainfall probability estimates and would provide a partial solution to some of the more pressing flood hazards (like the recent

March and April 2014 flood events). The designs would not, however, address the flood risks associated with more extreme events. The Ōpāwaho/Heathcote River area floods near the estuary entrance are not considered in the scope of the aforementioned proposals but will shortly be addressed via a separate series of proposed solutions. Both of the Dudley Creek options would also take an estimated two years to implement. These are considered to be more near-term and focused actions, similar to the incremental policy taken by the Drainage Board that became part of the CCC in 1989 (CCC, 1989).

3. Develop an updated storm management plan for the Ōpāwaho/Heathcote River. Properties in the river basin have experienced repeated flooding in March and April 2014. Studies similar to those undertaken for the Dudley basin are underway for the Ōpāwaho/Heathcote River areas.

4. Expand the flood management areas. In 2011 the CCC amended the District Plan through Operative Variation 48.[5] This document forms the basis for the updated *Natural Hazards Chapter* of the District Plan which is currently in development and in which Christchurch is proposing a 30% increase in the size of the FMAs. This update will provide the CCC with more consent (building permission) control in high hazard areas and also ensures disclosure of flood exposure through the Land Information Memorandum (LIM) process.[6] This potential policy consideration would help ensure that any new development (or significant redevelopment of existing buildings) incorporates flood mitigation measures.

5. Incorporate regional storm water management into the planning for the future use of the RRZ. The RRZ may be a key asset for regional flood hazard management. The RRZ can be used to increase conveyance and detention capacity, particularly for water collected north of the Ōtākaro/Avon River in Christchurch; and similar opportunities may exist for Red Zone lands in Waimakariri District as well. Enhanced storm water options may provide long-term benefit for the region's economy and a substantial multi-hazard risk reduction solution for its residents.

CERA recently announced that planning for the future use of RRZ would commence in 2014 (CERA, 2014b). RRZ planning might consider which areas are most appropriate for stormwater detention and conveyance and, as such, what easements and conditions of use (e.g. how much water, and for how long detained) are needed, and how conveyance would be managed into the estuary or other outlet. Prior to establishing the Residential Red Zone, the CCC had adequate authority through the Christchurch District Drainage Act (1969) to acquire and utilize lands within its geographic limits for conveyance. Once purchased, the RRZ lands become Government property, and an agreement for easement and use, and acceptable payment program,

---

[5] See http://resources.ccc.govt.nz/files/Variation48-OperativeDocument.pdf

[6] A LIM contains all the information that the Council holds on a property including: special characteristics of the land or buildings any current requisitions issued by the Council on the property, drainage information relating to sewer and/or storm water, and resource consents issued in the immediate neighborhood (default radius of 100m). (http://www.ccc.govt.nz/homeliving/goaheadbuildingplanningS00/propertyinformation-s09/limcontent-s09-02.aspx).

the scoping of necessary works may need to involve the CCC (and Waimakariri District, depending upon the scope), ECAN, SCIRT, EQC, CERA, the Government and other property owners as necessary.

6. Develop and implement collective agreements on an expanded scope of work for storm water improvements made as part of the earthquake recovery. In areas where earthquake land alterations have changed the runoff and flow characteristics (i.e. higher water table levels) and thus exacerbated flood risk, collective agreements on enhanced storm water conveyance improvements (to a pre-determined flood (storm) risk management level) may help reduce the recurring flood impacts in some neighbourhoods for small to medium size events. Special improvement areas could be designated to manage the upgrading on an on-going basis. The working party might involve the CCC (and Waimakariri District, depending upon the scope), ECAN, SCIRT, EQC, and CERA. Such a solution might also involve some alterations on private property. It should be noted that it is also unlikely to prevent the effects of large (low return interval) future events and can only be sustainably implemented where sea level rise effects will not cause gravity drainage problems.

SCIRT might be engaged to perform some of the necessary work. However, SCIRT's current scope of work and budget are based on a policy directive of replacing earthquake damage with "like-for-like" solutions. Recent flooding in March and April 2014 suggest that the like-for-like approach to returning to pre-earthquake conditions may not be sufficient to manage the new stormwater management issues resulting from the CES. SCIRT has the engineering capacity as well as the delivery capacity to execute projects as directed by the owner partners. As an owner-participant in SCIRT, the Christchurch City Council (CCC) might make the case for increased storm-water protection. Also, the CER Act defines recovery as including "restoration and enhancement" (CERA, 2011) and, thus, may provide the necessary statutory language for CERA to support SCIRT in designing and implementing enhancements to the storm drainage system as part of its earthquake-related repair and rebuilding work.

Any scope changes would likely require an adjustment in the SCIRT delivery schedule and the overall budget. To help finance this work, the owner partners might be able to use EQC funds for the neighborhood-level costs related to improve local conveyance and reduce potential stormwater impacts on EQC land damaged insured properties. EQC funding for properties with earthquake identified land impacts might be directed to help offset costs for the necessary neighbourhood flood improvements. EQC has been working to identify properties potentially affected by IFV using topographical information and modeling of the river flow and overland flow (effects of rainfall) for the Pūrākaunui/Styx, Ōtākaro/Avon and Ōpāwaho/Heathcote Rivers. Information from these studies will establish a basis for choosing schemes for the EQC contribution to the problem solution. These works could complement more regional stormwater management efforts that might address conveyance and storage along the Ōtākaro/Avon River, Ōpāwaho/Heathcote River and other major tributaries.

The problem at hand requires a policy directive that drives the engineering solution. This starts by accepting the 'new conditions' in the region (Alesch and Siembieda 2012), and, through a broad based sense of necessity, closes the present water management network gaps. The CERA Recovery Strategy for Greater Christchurch (Section 2) speaks to "*working together, taking an integrated approach, and looking to the future*" (2012). This is an adequate basis for a multi-stake holder conversation to take place.

References

Canterbury Earthquake Alesch, D. and W. Siembieda, 2012. "The role of the built environment in the recovery of cities and communities from extreme events." *International Journal of Mass Emergencies and Disasters*, 32(2), 197-211.

Canterbury Earthquake Recovery Agency. 2013. Land Use Recovery Plan. December.

Canterbury Earthquake Recovery Agency (CERA). 2014a. Residential red zone. http://cera.govt.nz/land-information/red-zone

Canterbury Earthquake Recovery Authority. 2014b. "Community to Have Say on Red Zone's Future." http://cera.govt.nz/news/2014/community-to-have-say-on-red-zones-future-17-april-2014.

Christchurch City Council. 2014. Draft Natural Hazards Chapter, District Plan Review (March).

Christchurch City Council. 2012. Updated residential floor areas for areas throughout Christchurch (October). http://resources.ccc.govt.nz/files/Homeliving/buildingplanning/floorlevels/FloorLevelsUpdateOct2012web.pdf

CCC, Christchurch City Council. 2011. Management of Flood Hazard in Christchurch. Operative Variation 48, Resources Management Act 1991. City Plan Amendment. http://resources.ccc.govt.nz/files/Variation48-OperativeDocument.pdf

Christchurch Drainage Board. 1989. Swamp to City: A Short History of the Christchurch Drainage Board from 1875-1989. Lincoln, NZ: Te Waihora Press.

Earthquake Commission. 2012. Cover: an Insurers Guide. http://www.eqc.govt.nz/what-we-do/eqc-insurance/insurers-guide

Earthquake Commission. 2014. Land with an increased risk of flooding. http://www.eqc.govt.nz/canterbury-earthquakes/land-claims/flat-land/increased-risk-of-flooding.

ECan, Canterbury Regional Council. 2014. Draft Annual Plan 2014-2015. http://ecan.govt.nz/publications/Plans/draft-annual-plan-2014.pdf

Jacobs-SKM. 2014. Land Drainage Recovery Programme: Dudley Creek - Options for Feasibility Report. Christchurch City Council. March.

Miles, S. D., Brechwald R., Davidson, K. Demeter, D. Johnston, S. Panpanin, and S. Wilkinson. 2014. "Building Back Better" Case Study of the 2010-2011 Canterbury, New Zealand Earthquake Sequence. EERI Report with the NZSEE and the Natural Hazards Platform for the Global Facility for Disaster Reduction and Recovery of the World Bank. Oakland CA: EERI. February.

New Zealand Parliament. 1993. Earthquake Commission Act. Public Act 1993, No. 84. Parliament Counsel Office: Wellington, New Zealand.

New Zealand Parliament. 1991. Resource Management Act 1991. Public Act 1991, No. 69. Parliament Counsel Office: Wellington, New Zealand.

New Zealand Parliament. 2002. Local Government Act 2002. Public Act 2002, No. 84. Parliament Counsel Office: Wellington, New Zealand.

New Zealand Parliament. 2011. Canterbury Earthquake Recovery Act 2011. Public Act 2011, No. 12. Parliament Counsel Office: Wellington, New Zealand.

Recovery Agency (CERA). 2012. Recovery Strategy for Greater Christchurch. May.

Rogers, Nick, Kate Williams, Mike Jacka, Shamus Wallace, and John Leeves. 2014. "Geotechnical Aspects of Disaster Recovery Planning in Residential Christchurch and Surrounding Districts Affected by Liquefaction." *Earthquake Spectra* 30 (1): 493–512. doi:http://dx.doi.org/10.1193/021513EQS029M.

Statistics New Zealand. 2010. "New Zealand Official Yearbook 2010". 107th edition. Statistics New Zealand.
http://www3.stats.govt.nz/New_Zealand_Official_Yearbooks/nz_official_yrbk_2010.pdf.pdf.

Stronger Christchurch Infrastructure Rebuild Team. (2014). The Value of SCIRT (Interim Report). Christchurch, NZ. January 31.

T&T, Tonkin & Taylor Ltd. 2013. Liquefaction vulnerability study. Earthquake Commission. T&T Ref: 52020.0200/v1.0