There's more to life than Earthquakes; there's also Tsunami, Flood and Wildfire to consider - Practical Application for Disaster Resilience

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ABSTRACT

The Waimakariri District Council recognised that the District is subject to a number of natural hazards and there was a need to better understand this risk. In 2007 the Council commissioned a Disaster Resilience Assessment for its three waters assets.

Since the original assessment, a range of new hazard studies were undertaken and the District experienced its first significant natural disaster, the September 2010 earthquake. This provided an excellent opportunity to reconsider hazard risks and incorporate lessons learned in a 2012 update.

Population centres in the District are concentrated in the east, in areas susceptible to liquefaction, flooding, tsunami, and wildfire. Individual site risk assessments formed the core of the study, based on severity, consequence and likelihood of failure. Understanding which assets are at greatest risk enables mitigation works to be undertaken and assists in response planning.

The Disaster Resilience work has provided Council with:

- Prioritisation of which assets are most at risk
- Reticulation vulnerability scores enabling risk-based water mains renewals programming
- Identified processes and actions to improve Council's readiness
- Actions for the capital budget to increase the resilience of utilities assets

This has been a valuable exercise which is assisting Council to achieve more robust and resilient utilities infrastructure and meet future community expectations.

KEYWORDS

Disaster, resilience, lifelines, water, wastewater, drainage, risk, hazards, earthquakes, renewals forecasting, lessons learned, asset management.

1 INTRODUCTION

The Waimakariri District is subject to risk from many natural hazards including earthquake, tsunami, flooding and meteorological events and man-made hazards including terrorism/sabotage. The Waimakariri District Council (WDC) recognised that more work was needed to ensure the Council were in the best possible position to respond to a major natural disaster such as an earthquake.

AECOM were commissioned in July 2007 to undertake a dedicated lifelines project (called a Disaster Resilience Assessment) for the water, wastewater and drainage services. This study was the first real attempt to undertake a lifelines assessment and identify risks from natural hazards in the Waimakariri District. This study was revised and updated in 2011/12 to incorporate new hazard information, new assets and lessons learned from the 2010 and 2011 Canterbury earthquakes.

The Waimakariri District Council commissioned the Disaster Resilience Assessment to identify assets at high risk and develop a mitigation plan to address these risks. Incorporating mitigation actions into business as usual asset management allowed spending to be prioritised against other drivers such as levels of service and growth.

2 WHY DISASTER RESILIENCE

The Waimakariri District is located in an area rich in natural resources. The District contains a number of large rivers, foothills to the Southern Alps and a section of the Pegasus Bay coastline. Figure 1 shows the location and some of the features in the District.

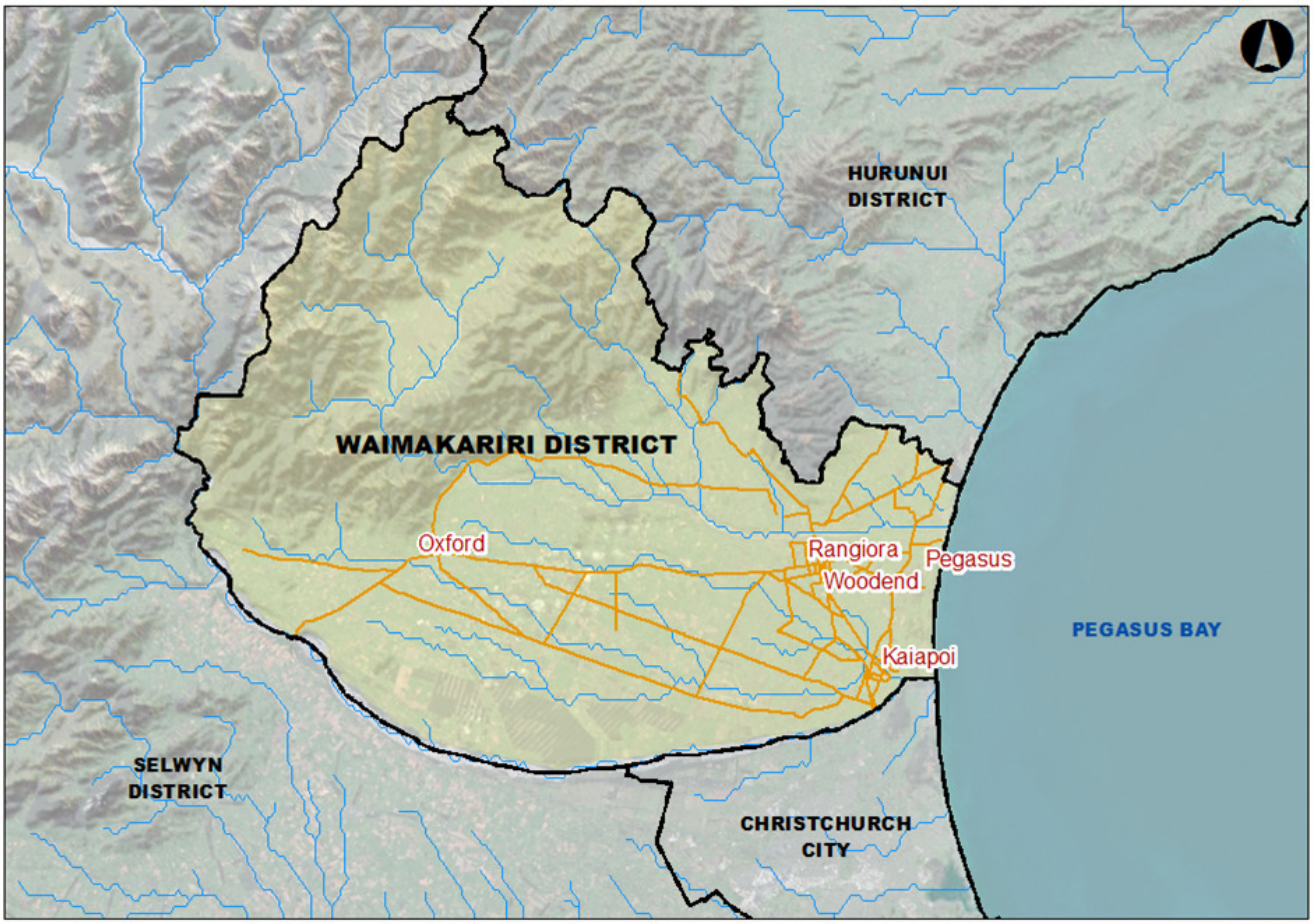

Figure 1: Map showing Waimakariri District

Council recognised that living among these natural resources presents a risk to built infrastructure through natural hazards. When reviewing the 2004 Asset Management Plans, WDC determined that more work was required to ensure the Council was in the best possible position to respond to a major adverse event.

Traditionally in the Council, effective response and actions to increase resilience has relied on local knowledge and intuition of a few individuals which puts the organisation at risk. With commissioning of this study, there was a conscious decision made to develop a robust and transparent methodology to determine which assets were most at risk when you have multiple schemes serving very different populations. A secondary driver was to document processes and develop plans and agreements to ensure opportunities to increase resilience were taken and effective response occurs.

One of the over-arching requirements of the Disaster Resilience Assessment was for the Council to improve their understanding of the highly critical and high risk assets. In addition, the CDEM Act requires all lifeline utilities to operate to the fullest possible extent before, during and after an emergency. To improve performance against this requirement, forward planning and some capital investment will be required. The Disaster Resilience Assessment identified areas for improvement, both in terms of Council processes and physical works to increase readiness and resilience. The identification of high risk and critical assets is fundamental to prioritising response.

3 WHAT ARE THE HAZARDS?

The Waimakariri District is separated from Christchurch City by the Waimakariri River to the South, borders the coast in the East and the Foothills to the West and North. The combination of coast, rivers and mountains makes the District a highly desirable place to live but also presents a number of hazards to its communities.

The eastern parts of the District are home to the highest concentrations of population who reside on the plains and underlying alluvial sediments. Due to their location, Council assets are subject to a large number of hazards including (but not limited to):

- River flooding – at its worst, greater than 2 metres inundation at a number of sites in Kaiapoi, Pines Kairaki and Woodend as a result of an Ashley River or Waimakariri River breakout

- Tsunami – 1.7 metres inundation at one wastewater pump station and half a metre of inundation possible at two other sites as a result of a worst case (high tide) distant source tsunami
- Wildfire – extreme and high risk wildfire hazard at a number of sites across the District
- Earthquake and liquefaction – a number of fault lines in the District and high liquefaction risk in the east

The communities in the District are served by a number of discrete schemes that include water, wastewater, drainage and stock water services. Eastern parts of the District are largely urbanised and served by on-demand water supplies and shared wastewater treatment and disposal which includes an ocean outfall. Central and Western parts of the District are rural in nature and largely served by restricted water supplies with small wastewater treatment plants and septic tank effluent pumping (STEP) systems. Drainage reticulation is used in some areas of the District with stormwater pumping required in the low lying areas of Kaiapoi.

As part of the Disaster Resilience Assessment, all above ground assets and reticulation across the District were assessed to determine vulnerability to a total of ten separate hazard events. An example of one of the hazard maps produced as part of the assessment can be seen in Figure 2.

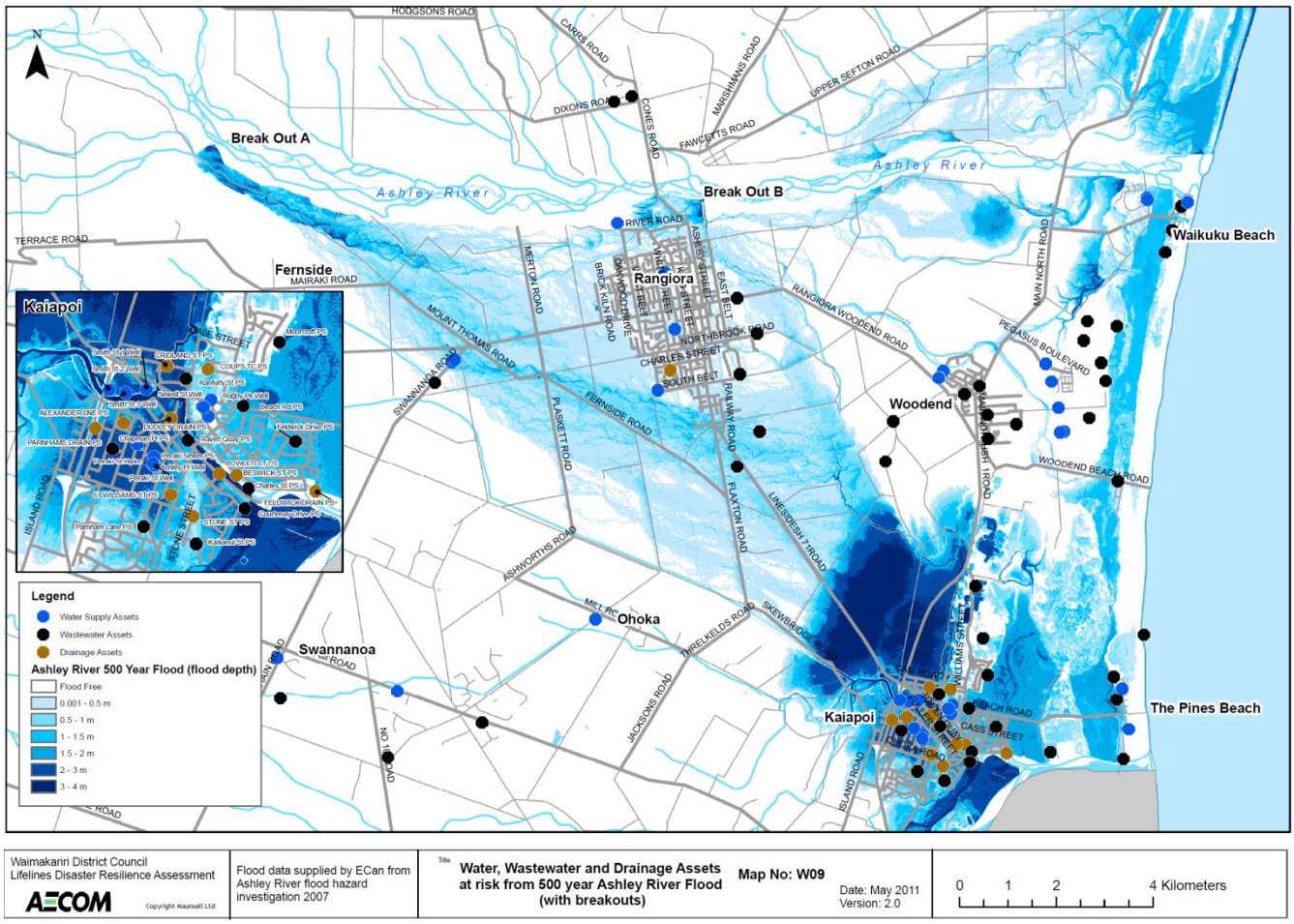

Figure 2: Map showing Flood Risk from the Ashley River Break Out on Above Ground Assets
(Flood modelling courtesy of Environment Canterbury)

To determine the risk to each individual site a number of factors were considered:

- The likelihood of the event occurring, determined by the hazard return period
- Consequences to public health
- Customers affected
- Consequences to the environment
- Financial impact on Council
- Wider economic impact to the community

Following the September 2010 earthquake, Council wanted to place further focus on the risk to reticulation assets. Three hazards were considered to have potential to impact on the reticulation; these are earthquake including liquefaction, flooding at waterway crossings and earthquake induced slope hazard. Risk to reticulation mains was assigned based on:

- Hazard vulnerability
  - Location relative to the hazard zone e.g. in the liquefaction susceptibility zone
  - Vulnerability of pipe material and joint type (seismic events only)
  - Likelihood of the event occurring (equivalent annual probability)
- Consequence of failure; taken directly from mains criticality (determined by a separate study)

These risk calculations showed that:

- 6 wastewater sites (above ground) and 2 water sites were at extreme risk from earthquake/tsunami.
- 36 water, 56 wastewater and 7 drainage sites were at high risk from flooding, earthquake, tsunami, wildfire or terrorism/sabotage.
- 11km of water supply reticulation, 10km of wastewater reticulation and 6km of drainage reticulation were rated as being at extreme risk from earthquake.
- 2km of water mains are considered to be at extreme risk from flooding at waterway crossings.

Figure 3 shows the distribution of high and extreme risk above ground wastewater assets.

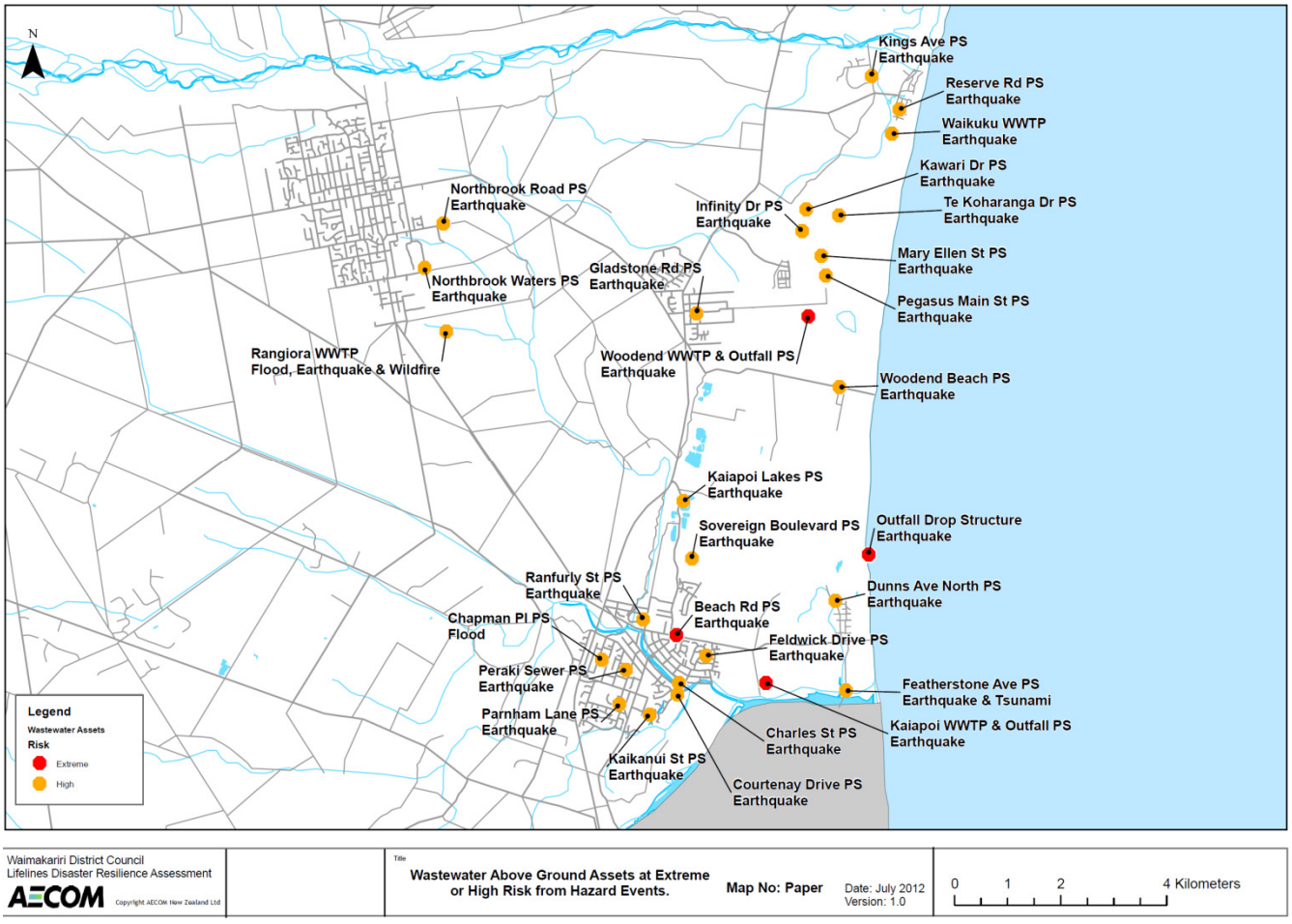

Figure 3: Map showing Extreme and High Risk Wastewater Assets

4 LEARNING FROM THE EARTHQUAKE

Prior to the September 2010 earthquake, WDC were implementing a number of actions as a result of the Disaster Resilience Assessment to reduce the risks identified, these were:

- Premature replacement of critical AC mains was prioritised as part of the water main renewals process to reduce risk to the network.
- The need for valves on critical waterway crossings had been highlighted. A new valve had been ordered for the 250mm AC main attached to the Williams Street bridge which connects north and south Kaiapoi. Unfortunately the valve wasn't able to be installed prior to the September 2010 earthquake, but was in the first few days after the earthquake.
- Assessments at the ten highest risk above ground sites had been carried out to identify physical works to increase resilience at these sites.
- Planning for update and further refinement of the Disaster Resilience Assessment.

The September 2010 earthquake then hit, leaving south eastern parts of the District heavily affected. Large areas of Kaiapoi, The Pines Beach and Kairaki were affected by liquefaction and 940 properties have been included in the red zone as determined by CERA, the Canterbury Earthquake Recovery Authority. The red zone is land that is uneconomic to repair and in these cases the government have offered to purchase insured properties.

4.1 RESPONSE LEARNINGS

The earthquakes provided the Three Waters Team with an opportunity to capture lessons learned and ensure they are included in future planning and mitigation works. A series of workshops were held in May 2011 with water and wastewater contractors, internal utilities and operations teams (The Water Unit) and other WDC teams including the in house Project Delivery Unit, IT, Finance, GIS and Civil Defence.

The workshops focused on what went well and opportunities for improvement. The key areas of feedback from the teams included:

4.1.1 WHAT WENT WELL

- The relatively small size and responsiveness of the organisation with appropriate levels of delegation, meant that there were only two steps between the field staff and the Chief Executive. This resulted in effective communication and a dynamic response.
- Experienced asset management and operations staff that knew the assets well leading the response and recovery.
- The relationships with contractors and their willingness to assist throughout the response and recovery phases.
- The main utilities and Council headquarters remained operational, providing a base from which to co-ordinate and allow access to electronic data including GIS. There is significant value in ensuring your base or headquarters is as resilient as possible.
- Early aerial reconnaissance provided an accurate picture of the scale and severity of hazard impacts and allowed prioritisation of response. An agreement with your local provider is useful for a quick response.
- Allocation of work to contractors by geographical area provided an efficient way of working and allowed progress and results to be seen. Use of experienced internal staff to manage contractors worked very effectively.
- Regular staff debriefs including catering for crews was highly valued and allowed prompt and structured feedback on progress and priorities and sharing of ideas.
- Regular public communications including door knocking and letter drops was well received by the public during response.

- Supplier response was excellent and a temporary depot was established near the response area to provide crews with the necessary parts and materials.

4.1.2 OPPORTUNITIES FOR IMPROVEMENT

- Availability of fuel was difficult and negotiation of priority fuel supplies for operations and contract teams would reduce disruption to ground crews.
- Appointment of a specific Contractor Resource Manager to direct and manage resource would be beneficial. The input from contractors was highly valued by Council.
- Implementation of emergency stock control arrangements that allow monitoring of stock use and charging.
- Availability of alternative forms of communications was critical following mobile communication failure. A dedicated radio frequency for water and wastewater operations would be beneficial.
- Whilst production of hard copy plans worked well it was a lesson learned that up to date network plans were highly valued by contractors and staff. Resilience could be increased by producing and storing hard copy plans off site supplemented with electronic PDF mapbooks which allow non GIS staff to produce plans rapidly.

4.2 RESILIENCE LEARNINGS

The top three high level learnings from the September 2010 earthquake were:

- WDC is generally able to respond well to a "moderate sized" natural disaster
- A number of WDC assets are very vulnerable to natural disasters
- A better appreciation of risk needs to be considered in a renewals programme

In a more detailed analysis, the reticulation network in affected parts of the District suffered significant damage. Approximately 9.2km of water mains and 7.1km wastewater reticulation has been or is scheduled for replacement due to earthquake damage. The Waimakariri District Council and the Christchurch City Council shared pipe performance information and held discussions that allowed each Council to make decisions on the most appropriate materials and methods to use in high risks areas.

The Council has made the decision to replace all water mains in high risk liquefaction zones with welded PE when they are due for renewal. The benefits of PE and PVC were debated by Council and others. PVC generally performed well during the earthquake, it provides a high level of resilience and is considered easier to repair in difficult conditions. The performance of non restrained joints in some areas of liquefaction and lateral spread has led Council to this decision. An example of a failed PVC joint is shown in Figure 4.

Figure 4: Re-insertion failure of PVC pipe

The Council has been reviewing generator provision for their above ground assets. The allocation of generators is based on asset criticality. As a result of changes in asset criticality and installation of new assets, generator provision is being reviewed, prior to further planned capital investment.

5 MITIGATION ACTIONS

Over the last few years, Council have undertaken a number of studies that made recommendations to increase resilience. All known readiness, response and asset resilience actions from these studies were assembled into a prioritised Implementation Plan. As the Disaster Resilience Assessment demonstrated earthquake represents the most prevalent risk to assets in the District, earthquake related actions were prioritised along with quick wins relating to response planning.

The list below represents the short term actions that have been recommended from the Implementation Plan:

1. Review of WDC **Design Standards**; including above ground assets, generator provision and reticulation.
2. Implement **Recommendations of Headworks Assessments**; undertake minor capital improvements and housekeeping actions identified for the 10 extreme risk sites (from the original DRA) – quick win
3. **Review Resilience of Depots and Service Centres**; secure all furniture and equipment to prevent damage in a seismic event. Water Unit, TSU and Utilities Offices. – quick win
4. Improve understanding of **Liquefaction Risk**; monitor new information including areas outside the current liquefaction mapping area
5. Investigate options to **Reduce Extreme and High Seismic risk** to Schemes (including reservoirs); investigate options to reduce unacceptable levels of risk these could include joining schemes, redundancy or strengthening works
6. Secure adequate **Generator Provision**; purchase additional generator in line with Generator Strategy recommendations - quick win
7. **Validate** accuracy of **Asset Register** reticulation data particularly relating to main material
8. Include **Vulnerability Assessment in Mains Renewals**; Water, Wastewater and Drainage.
9. Develop **Emergency Water Supply Mechanisms;** design and manufacture devises - quick win
10. Establish **Emergency Fuel Supply Arrangements;** arrangements for priority and emergency supply - quick win
11. Review **Backup Radio Provision** for 3 Waters Team; purchase of additional frequencies, additional radio units and training.
12. Develop **Emergency Resource Management**; processes for emergency stock control and resource management including management of contractors and work allocation
13. Document **Emergency Response Arrangements** (Utilities Succession Planning); document arrangements that were found to be effective to provide succession planning
14. Review **Vehicle Provision** for emergency response; ensure vehicles are suitable and equipped - quick win
15. Annual maintenance of **Essential Customers** list; review and maintain considering lessons learned from the earthquake
16. **Review Disaster Resilience Implementation Plan** annually.

Not all of these recommendations will be acted upon within the first year, and some of them have already been carried out.

A number of points from this list, such as 4 and 5, involve further investigations which will lead to site specific actions being created once there is better understanding of the individual risks to each site.

6 DISASTER RESILIENCE IN ASSET MANAGEMENT

Having identified vulnerable and at risk assets and determined suitable mitigation actions, the most critical stage of the process is embedding actions and processes into business as usual activities. WDC has included work from the DRA in two key pieces of work to ensure forward planning work increases resilience across all three waters assets. The asset management plans for both 2009 and 2012 incorporated dedicated disaster resilience sections, and a new risk-based renewals process has been adopted for water mains, and will be adopted for wastewater and stormwater in 2012.

6.1 ASSET MANAGEMENT PLANS

One of the keys to the inclusion of disaster resilience into the core business is ensuring planned improvements are incorporated into the Council's Asset Management Plans (AMP's). This enables spending on mitigation actions to be prioritised against other drivers such as level of service improvements and growth. In WDC's 2009 edition of the AMP, there was a dedicated section on disaster resilience for each water and wastewater scheme stating the level of risk for each asset associated with that scheme for all of the hazard events.

For the 2012 AMP revision, the disaster resilience section has been updated to include all drainage schemes and identify mitigation actions for the high and extreme risks. The mitigation actions designed to increase resilience to the most urgent and highest risks have been included in the improvement plan and the budgets. These mitigation actions came directly from the Disaster Resilience Assessment and Strategy.

Council developed a Disaster Resilience Strategy to provide direction to implementation actions to increase readiness and resilience of the three waters assets. The strategy aims to support the case for expenditure on physical works and actions to increase readiness.

6.2 RISK BASED RETICULATION RENEWALS

WDC has incorporated the disaster resilience work into asset management by adopting a risk based renewals programme. Initially this has been rolled out for water main renewals with wastewater and drainage renewals to follow over the next 12 months. Traditionally the water mains renewal programme had been based on two factors:

- the theoretical remaining life of the mains
- operational knowledge from the Asset Manager

The renewals programme did not take into account risks or criticality of water mains. For example; a 100mm steel main feeding 100 properties with 10 years remaining useful life was given a higher priority than a more critical and more vulnerable 300mm diameter Asbestos Cement main feeding 1,000 properties that has 11 years remaining useful life. Previously, the renewal priority did not take the criticality of the main or the consequence of failure into account.

Furthermore the renewal priority did not take into account the vulnerability of the main to damage, for example a flexible main such as PVC in good ground, was given the same priority as a brittle main such as AC in ground susceptible to liquefaction.

The increase in seismic risk in the District as a result of the 2010 earthquake sequence has highlighted the need to better understand the risk of earthquake related water mains failure and the need to prepare a renewals programme that is based on reducing this risk.

As part of the new risk based approach to mains renewals; three main factors were used to determine the likelihood of mains failure across the District:

1. The burst history of the water main, as an indicator of condition.
2. The theoretical remaining useful life. This is still an important factor as it provides us with the age of the main compared to how long it is expected to be serviceable.
3. The vulnerability of each water main in the District, determined using:
    - Location of the main considering the liquefaction potential of the ground, any waterway crossings or location in a slope which could potentially be unstable in an earthquake.
    - The ductility of the main material, i.e. PVC mains are more resilient to movement than asbestos cement mains.

- Jointing method was also considered, a significant amount of joint failures occurred during the earthquake with non-restrained joints failures occurring on a number of pipes.

These three factors were evaluated and combined to provide an overall likelihood of failure score for reticulation mains.

The consequence of failure was denoted by the criticality of each water main, taking into account the population served, diameter, critical customers and location, e.g. strategic road or railway line.

The likelihood and consequence of failure were combined to give a risk score to each water main in the District. Table 1 shows an example of how the revised methodology gives significantly higher priority to critical and vulnerable mains in the renewals programme. For example, the 375mm main on Sewell Street has been prioritised (due to its criticality and vulnerability) over the 100mm main with a shorter remaining useful life. Using the previous renewals method, this main would not have been highlighted for replacement at all, now it is considered to be the highest risk main in the District.

Location	Diameter (mm)	Material	Criticality	Vulnerability	Remaining Useful Life (years)	Risk Score
Sewell Street, Kaiapoi	375	Asbestos Cement	AA	Extreme	27	6500
Holland Drive, Kaiapoi	100	Polyethylene	C	Medium	15	248

Table 1: Risk Based Renewals Scoring

Figure 5 shows the mains vulnerability in Kaiapoi for all water mains, calculated for the renewals programme. Figure 6 then shows the actual damage to water mains in Kaiapoi from the September 2010 earthquake by showing where repairs were carried out and where mains where re-laid in the first 10 weeks after the earthquake. These maps clearly show that the methodology was robust, as the highest vulnerability mains suffered the greatest damage.

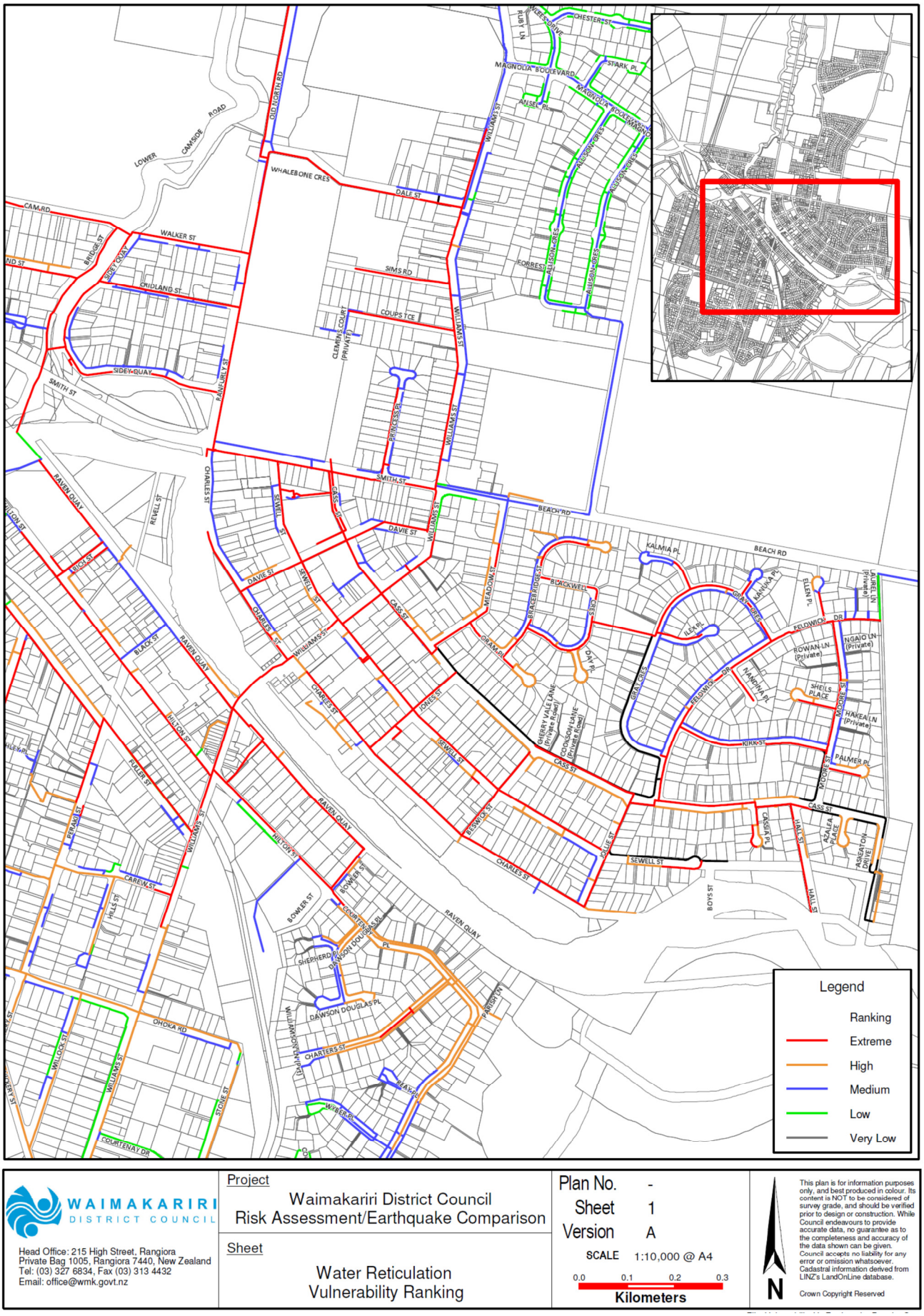

Figure 5: Water main vulnerability in Kaiapoi

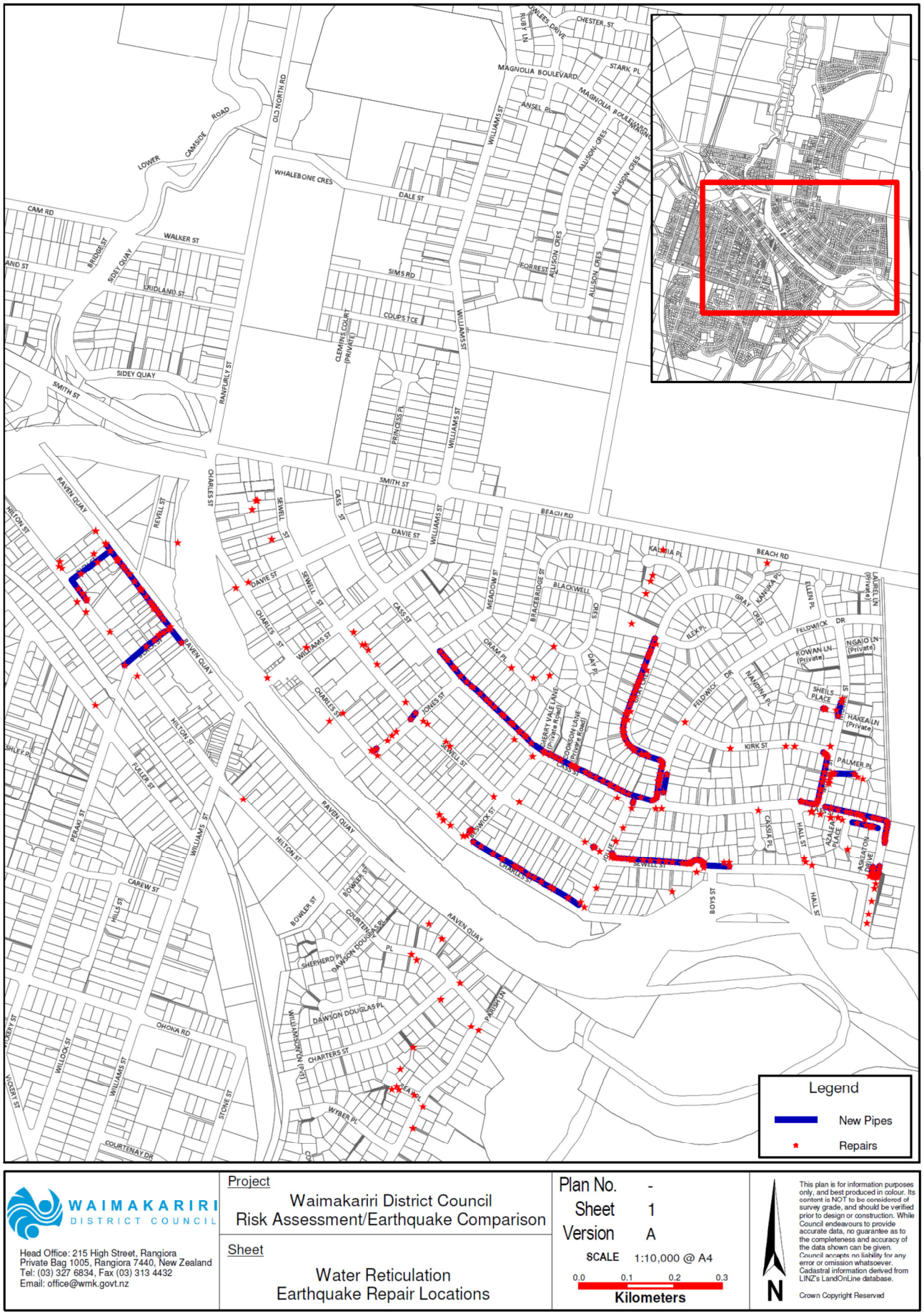

Figure 6: Damage to water mains from September 2010 earthquake in Kaiapoi

This ranked list of at risk mains does not mean the highest scoring main will fail, the decision not to replace a number of less critical mains until they actually fail is a valid one. However it does highlight a level of risk that the Council is prepared to accept with regards to supplying drinking water.

The results of our risk based reticulation renewals have shown that:

- 90 out of the 100 highest risk mains are made of asbestos cement.
- The 100 most at risk pipes represent 1.6% of the total length of reticulation in the District with a value of $2 Million.
- 83 of the top 100 at risk pipes are located in Kaiapoi. This is the area that suffered substantial damage due to the earthquake.

The risk profile shown in Figure 7 shows the projected reduction in risk based on the average annual renewals budgets over ten years. This projection makes the assumption that all budgeted renewals money will be spent on risk reduction. In reality, there are other drivers including aligning with other utilities renewals such as footpath renewals and underground cabling works that the water main renewals programme needs to be aligned with.

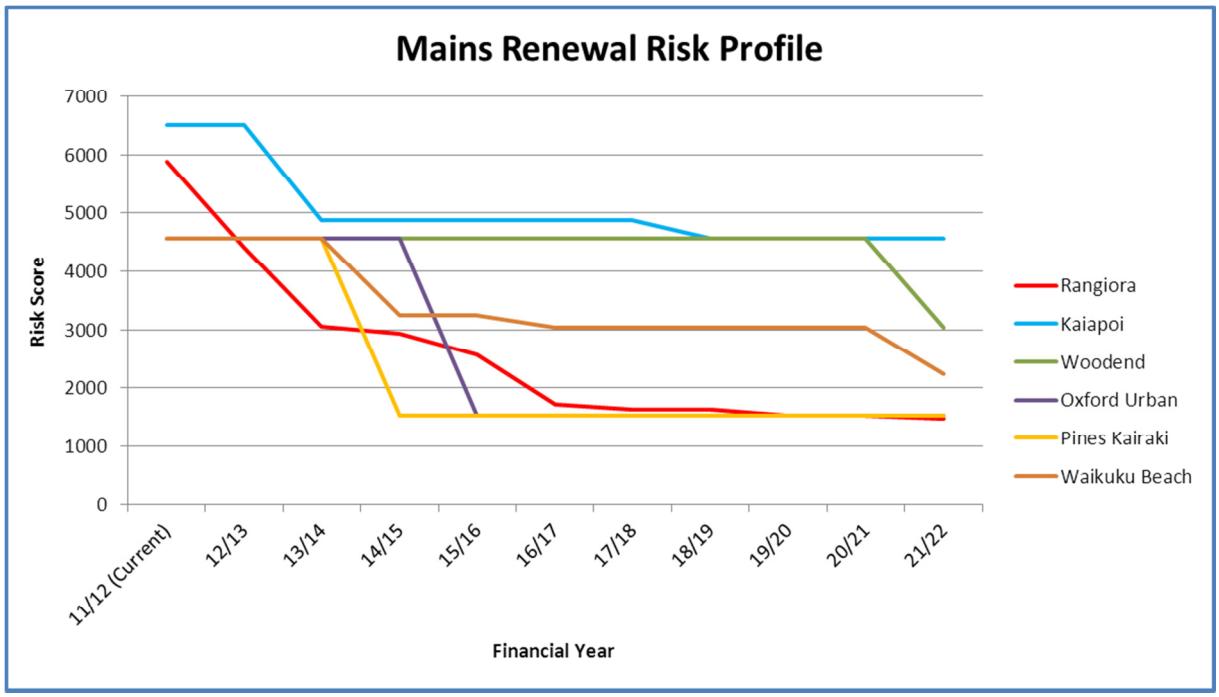

Figure 7: Mains Renewal Risk Profile for Six Water Supply Schemes

Appropriate levels of risk were determined for each water supply scheme, which provides a justifiable renewals budget for the next ten years. Based on this work, an accelerated renewals budget was planned for Kaiapoi to reduce the overall risk on the reticulation network.

Once the risk based renewals programmes are established for wastewater and drainage reticulation, a risk based renewals process is planned to be developed for the above ground assets.

7 WHAT COUNCIL HAVE GAINED

Since the study started in 2007, the Waimakariri District Council have benefited from the disaster resilience work in a number of ways:

- Greater understanding of risk to all three waters assets from natural hazards.
- Ability to prioritise response actions.
- Vulnerability scoring for all reticulation allowing risk based renewals process.
- Greater understanding of processes required in a response situation after an event.
- Know where to target spending to increase resilience
- Demonstrate resilience of network to insurers.

When the study was first commissioned, all of the expected outcomes were not fully understood. It is likely that there will also be other benefits realised from further work carried out that are yet to be understood.

8 NEXT STEPS

Despite the update of the Disaster Resilience Assessment being complete, the work does not stop there. There is a significant amount of ongoing study required to gain better understanding of the risk posed by the hazards. For example, a study to remap the liquefaction risk across the District which would provide a better understanding of the risk using data from the recent earthquakes and has just been completed. This now needs to be incorporated into the assessment of all WDC assets both above and below ground.

In terms of the short term work for the WDC, the main priority is to further understand the risks posed at the extreme and high risk sites. Site investigation will be carried out this financial year to verify the extreme and high risk sites and identify options to reduce the risk. For some of the events at certain sites, there may be logical reasons why no mitigation actions are required. For example, the new secure water bores feeding Rangiora scored a high risk for local flooding, however when investigated further, the scoring on this site did not take into consideration the raising of the floor level above expected flood depths during construction. Therefore there are limitations to the desktop exercise that need further work prior to actual physical improvement work.

There are however, many other high or extreme risk sites that will require some physical mitigation works to be carried out, and the further investigations into these sites will recommend exactly what works are to be carried out and recommend appropriate budgets. There are already some budgeted items in the financial year to increase resilience at the ten extreme risk sites identified as part of the first edition of the DRA.

The other major focus for this financial year is to ensure the most critical sites have generators. The WDC currently has a number of fixed and portable generators at various sites. A study was undertaken in 2010 to determine what further generator provision was required and which sites are most critical in terms of generator provision. This study will be updated in 2012 with capital money budgeted to purchase generators.

The Waimakariri District Council understand that work to improve resilience of the three waters networks requires ongoing commitment. Council has incorporated disaster resilience into business as usual asset management to improve the resilience of existing assets and ensure future assets are as resilient as practically possible and provide a continued service following a hazard event.

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Martyn Wooster – Previously with AECOM

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