REFORMING LEAK DETECTION AND REPAIR OF CHRISTCHURCH'S EARTHQUAKE DAMAGED WATER SUPPLY NETWORK

J.Hall and M.Rhodes
Stronger Christchurch Infrastructure Rebuild Team, Christchurch, New Zealand

ABSTRACT

Following emergency repairs as a result of the February 2011 earthquake, the Christchurch water supply network was left in a fragile condition. Leakage levels were 2 times greater than prior to the earthquakes and the overall resilience of the network was not well understood.

This paper outlines how the Stronger Christchurch Infrastructure Rebuild Team (SCIRT) went about reducing leakage from the potable water supply network to pre-earthquake level and reforming how the water supply network is viewed, worked on and managed. The question authorities in New Zealand's other urban centres may be asking is: how unique were the circumstances described to Christchurch & what of this applies to us?

KEYWORDS

Leak detection, minimum night flow test, seasonal irrigation offset, water supply, level of service

1 INTRODUCTION

The series of earthquakes in the Canterbury region of New Zealand from September 2010, especially the 22nd February 2011 earthquake, caused considerable damage to Christchurch city's ~3,000 km of underground water supply pipe infrastructure. The basic sanitary needs and living conditions of Christchurch's ~360,000 people were seriously disrupted by broken and leaky water supply pipes.

To determine the extent of damage to these pipes, over 30 people from various backgrounds came together within a few short months to inspect and fix the leaks. Because not all leaks come to the surface, listening for the sound that leaking water makes when under pressure was the most effective way of finding breaks in the pipes.

The challenge of doing this in 18 months across a city full of noise from demolition and construction was impressive both in its scale and complexity. It required effective and timely deployment of resources into unknown and unseen damaged areas.

Working in an ever changing environment, the people involved needed to challenge the status-quo. Flexibility and innovation was required to effectively respond to the demands of this technically challenging work.

2 TIMELINE

SCIRT's leak detection and repair project evolved from a reactionary earthquake start-up operation into a multifaceted business in just a few months.

After each earthquake, the big leaks apparent from the ground surface were quickly repaired. Remaining were ~3,000 km of pipe whose overall condition and resilience was not well understood.

These pipes could have small leaks unseen on the ground surface, slowly being enlarged by pressure and time until they rupture. Alternatively a critical joint may have been weakened, waiting to rupture in the next earthquake or when the adjacent ground is broken to effect repairs on other services.

The task was made all the more difficult by ongoing tremors, demolition and construction with many of the pipes buried under Christchurch's busy roads and residential streets.

Table 1 shows the sequence of events (aligned with the larger earthquakes in Christchurch) leading to the formation of the SCIRT leak detection and repair programme.

Table 1: Timeline of Events

Date	Activity
4th September 2010	Early emergency response phase from first earthquakes
22nd February 2011	Emergency response and infrastructure recovery to maintain services from the most damaging earthquake
13th June 2011	Development of a city-wide infrastructure plan, and the formation of SCIRT on 1st September 2011
23rd December 2011	A city-wide strategy of how to fix 100's of kilometres of pipe emerges, which next needs to be trialed
1st December 2012	The big fix begins
30th June 2014	Scheduled date whereby the average leakage across the network has been returned to a pre-earthquake level of leakage

3 OPTIONS

Having a defined purpose to return the water supply network to pre earthquake levels of service in 19 months, it had to be determined how this would be done. The key level of service that was the focus of this programme was to return potable water supply leakage levels (expressed as L/connection/day) to pre-earthquake levels. A secondary outcome was to assist SCIRT and the city in reducing the frequency of breaks in the water supply network to pre-earthquake levels. A number of options were considered and costed along with their strengths and weaknesses. Two options quickly stood out as being the most viable with the first being selected.

3.1 ACTIVE LEAK CONTROL ACCOUNTING FOR LEGITIMATE USE

This would allow leakage reduction to be carried out all year round by using three cycles of Minimum Night Flow Tests and leakage sweeps, targeting leaks through the use of step testing and repairing them. In practice this required developing a means to accurately quantify legitimate water use continuously throughout the year and logging sub main meters.

While allowing the 19 month programme to be met, this option would provide a view of each of the 158 Council delineated Water Loss Zones at a point in time only, not continuously. It also offers only a limited added benefit should another significant seismic event take place. To its credit, this option met the principal requirement to return the network to its pre earthquake level of service with respect to leakage and was the most cost effective option at $3.8m.

This option differed from CCC's pre-earthquake leak reduction programme in that it was run over a continuous 19 month period, rather than only during winter months. This added the complications of having to make an allowance for summer time domestic irrigation when assessing leakage levels.

3.2 ACTIVE LEAK CONTROL PLUS THE INSTALLATION OF PERMANENT METERS AND DATA LOGGERS

In addition to the above, this would continuously collect water network data from the Water Loss Zones. The collected data would be transmitted daily for monitoring and maintaining the leakage reductions gained, proactive management of leakage and mains/sub-mains bursts, and allow an understanding of the amount of leakage in the network at all times.

With an estimated cost of $15.2m it would be approximately 4 times costlier than the first option and result in an improved network. The installation of permanent meters and data loggers in the 158 Water Loss Zones would better facilitate re-establishment of the water supply system at any future point in time for any reason.

4 INNOVATIONS

4.1 THE PEOPLE

Prior to the earthquakes, pipe surveys were undertaken by a few local specialists to maintain the city's water supply network. Inspections were done in the winter months only so as not to confuse high summer water demand from garden irrigation with leakage. Typically a suburb of the city was reviewed once every 10 years.

Due to the post-quake fragility of many pipes and the desire to replace sections of pipe alongside other construction, it was determined all water loss zones needed to be inspected by June 2014. In order to achieve this, work would have to be carried out uninterrupted throughout the year and include substantial repairs and upgrades to reservoirs and the pipe network. If the alternative pre-earthquake approach to leakage detection was applied, the programme would have needed to be run over 4 winter seasons (to late 2016). This would have pushed the inspection and repair process beyond the end of the SCIRT rebuild programme and resulted in roading rebuild works occurring in areas where buried water supply pipework had not been inspected for leakage.

Simply upscaling the pre-earthquake model of testing the water supply network was quickly assessed as unviable. A different approach was needed and SCIRT engaged specialists from Europe and Australia to compliment the local knowledge and skill base. This achieved the cross-fertilisation of ideas and innovative thinking that was needed to find the leaks and fix the pipes in 19 months.

4.2 WORKING UNINTERRUPTED – SEASONAL IRRIGATION OFFSETS & WATER METERS

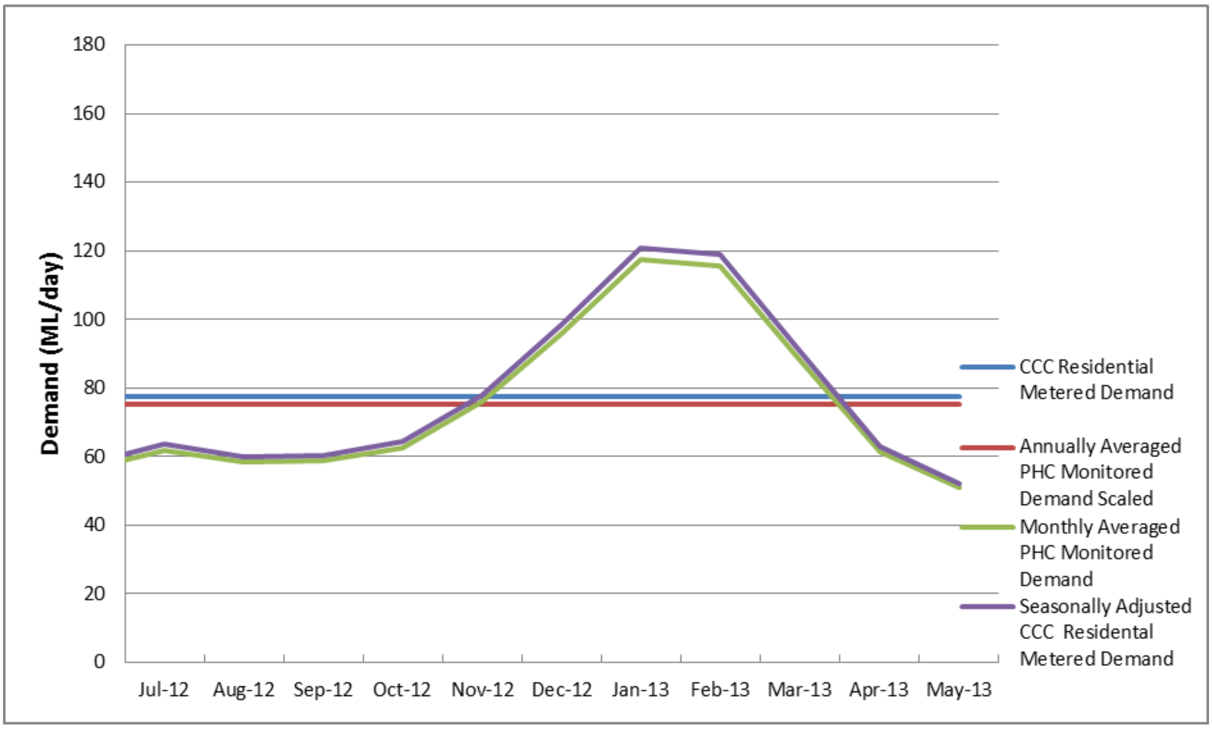
Leak detection surveys had traditionally been undertaken at night over winter months (May through to early September) when households are unlikely to irrigate gardens and night time water demand is at a minimum. This limited the number of Water Loss Zones that could be tested each year. To work uninterrupted, a methodology was needed to account for variable night time usage all year round.

With little exception, summer water usage between the night hours of 1-5am is for two purposes: irrigation of gardens & industrial processes. By measuring these accurately an offset can be applied to flow rates recorded during Minimum Night Flow Tests and allow work to carry on throughout the year.

Irrigation of gardens was modelled by establishing 19 sub main meters across Christchurch to monitor day and night water demand in residential areas. Flow and pressure data from these sites were transmitted via the mobile phone network to SCIRT and Christchurch City Council daily.

It was found that this data accurately correlated against the total metered demand. This meant that the 19 submain meter sites could be used collectively to model irrigation consumption in the city (see Figure 1).

Figure 1: Graph Showing Correlation Between the 19 Submain Meter Water Usage Vs. Total Metered Demand



Industrial use was more accurately assessed by linking Christchurch's 125,000 public water meters to Water Loss Zones and identifying high consumers whose meters were read during tests.

Combining irrigation and high water user's data, an offset could be calculated to work out the amount of water leaking from a Water Loss Zone during a test. Knowing this not only focused efforts on finding leaks and establishing the success of repairs, it also enabled the project to be completed in the 19 months rather than 48.

4.3 A LEVEL OF SERVICE (LOS) APPROACH

Work started in December 2011 in the most damaged Water Loss Zones, in the east of the City. In June 2013 SCIRT's funders challenged SCIRT to deliver the rebuild programme for a reduced budget. One way to do this was not to replace pipes which were assessed as having worthwhile remaining life and to repair remaining pipes to a standard similar to what they were in before the earthquake.

A number of levels of service for the water supply network existed and the way to ensure the majority of these were met was a combination of repairing all known leaks but only replacing pipes that were old or fragile.

A level of service approach also allowed gains made in improving the service to one Water Loss Zone to offset another where obtaining pre-earthquake service was proving uneconomical. Overall however, by 30 June 2014 the city's water network across all 158 Water Loss Zones provided a service equal to or better than before the earthquakes.

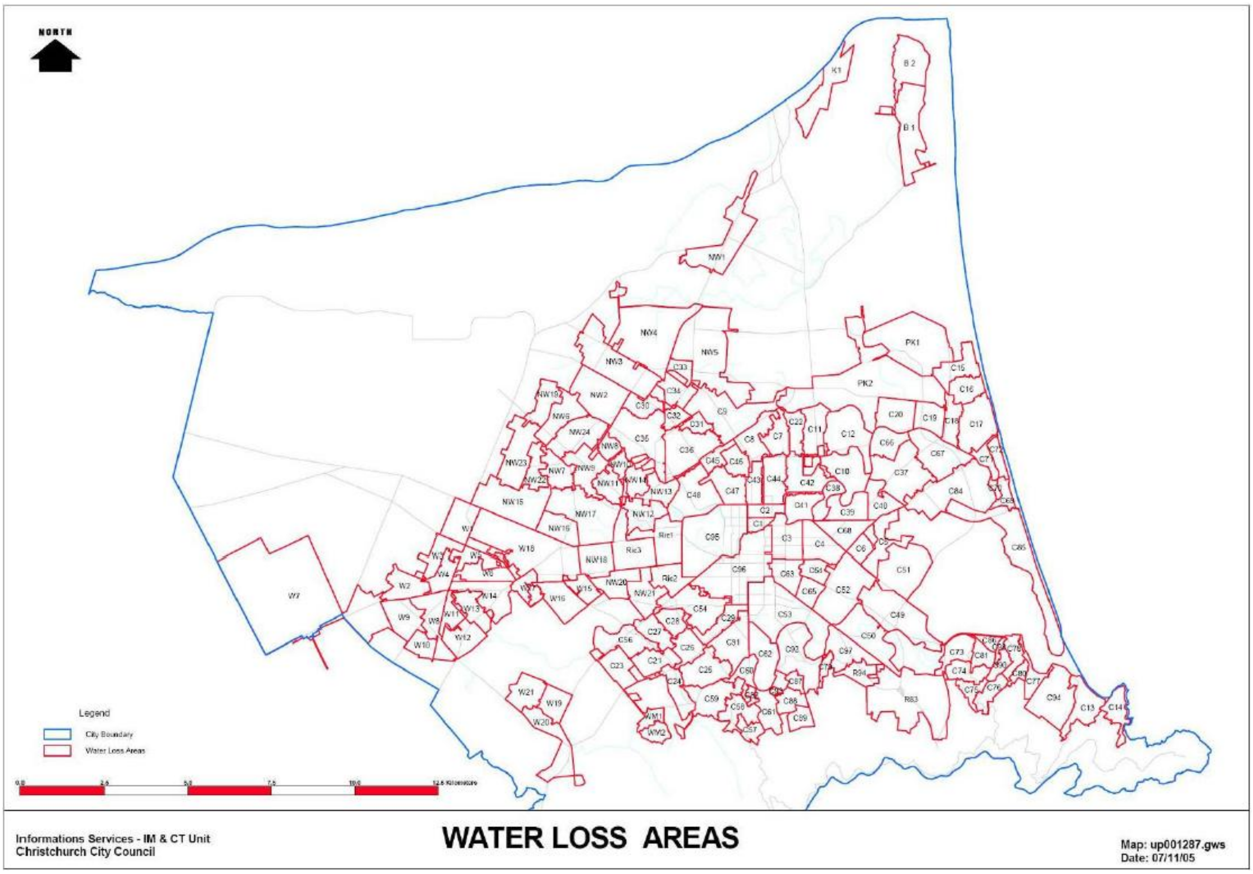
4.4 WATER LOSS ZONE TESTING

Prior to the earthquakes, a lack of supply points in hill Water Loss Zones or a means of measuring flow from reservoir outlets meant that not all Water Loss Zones could be tested to determine how much they were leaking. Post-earthquakes, their condition had to be tested.

A system using pressure reducing and sustaining valves was developed to bypass hill reservoirs while the installation of new valves, hydrants and flow meters completed the infrastructure necessary to test these zones.

Some Water Loss Zones included red zone land (land so badly damaged by the earthquakes that it is unlikely it can be rebuilt on for a prolonged period). This created complexity and necessitated changes to Water Loss Zone boundaries and in some instances equipment on the pipe network. This was used as an opportunity to re-define the boundaries of some of Christchurch's 158 Water Loss Zones (see Figure 2), rationalising them and allowing the work to be carried out more efficiently.

Figure 2: Map Showing the Water Loss Zones in Christchurch



4.5 WORKFLOW MANAGEMENT SYSTEM & REPORTING

It was estimated ~5,000 leaks would require repair in 19 months to return Christchurch's water supply network to pre Earthquake levels of service by June 2014. Compiling, tracking and managing the discovery, repair and payment for this work required a centralised management system.

The historical system relied on spreadsheet and email records which worked well when 150 leaks and repairs were managed each year. It however was no solution for the scale of operation ahead.

In less than 1 month SCIRT, in conjunction with City Care Ltd, developed a workflow management system that was GIS based and used a tablet to log leaks & repairs in the field and a software model called INFONET to process information and manage reports. The entire water supply network was accessible through tablets linked to the mobile phone network which allowed live reporting of leaks in the field that could be tracked for status and repaired faster. This also made processing payments easier. *Think how a courier company tracks its parcels and then link it to a map of the cities pipes*.

The first version was slow and the Information Technology developers were invited into the field to observe what tablet operation was like for the end users. This fostered a collaboration which meant a much more user friendly system was developed in less than a month - something an industry insider described as having been unsuccessfully tried several times previously in Australia.

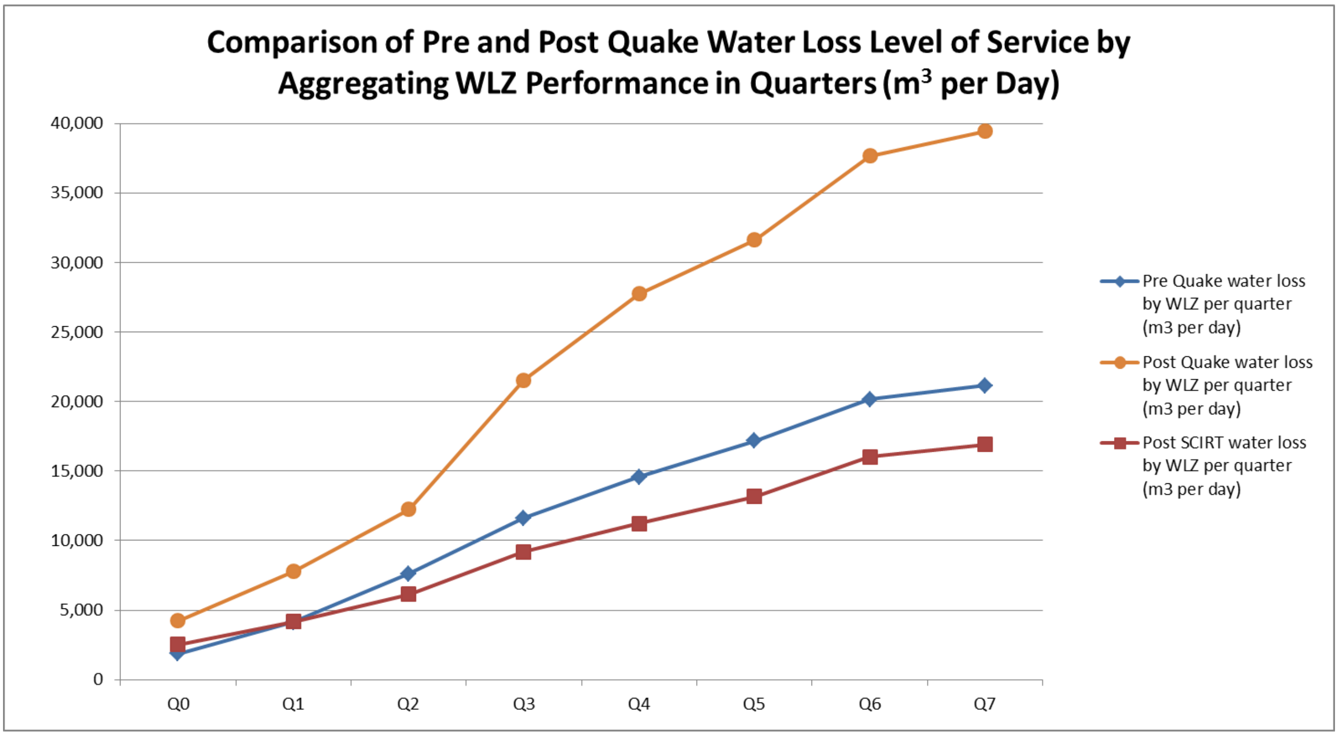
The use of technology undoubtedly provided the speed, flexibility and reporting required for the right decisions to be made on how to return the city's water supply network to pre-earthquake levels of service.

5 BENEFITS

Figure 3 shows the aggregated minimum night flow rate of all water loss zones assessed throughout the programme expressed in cubic metres per day. The pre-earthquake minimum night flow rate of all zones was c.21,100m^3 per day. After carrying out the initial minimum night flow test (without carrying out any leak repairs) the minimum night flow rate was almost double at c.39,400m^3 per day. By the end of the programme after completing leak repairs, the minimum night flow rate was reduced to c. 16,900m^3 per day.

The experience and innovations developed by the people involved in returning the water supply network to its pre-earthquake level of service will have a lasting influence on Christchurch. It will affect the future of asset management while giving confidence to local communities through a stronger water supply network. These benefits will continue to be realised beyond the rebuilding effort as contractors and engineers return to their home cities and provinces with this experience.

Figure 3: Comparison of Pre and Post Earthquake Water Loss Level of Service



6 CONCLUSION

While the earthquakes have changed the face of Christchurch, a heightened sense of engagement from working towards a common purpose has brought about many innovative solutions. This should not be missed by the rest of New Zealand's pipe survey industry.

With the funding available, the chosen methodology allowed a complete assessment and repair of the water supply network in 19 months. Resilience however could have been further improved with additional funding by introducing permanently logged district meters spread throughout the network also allowing continuous future monitoring and management of the network.

Undoubtedly the experience and diverse skills of the people involved coupled with a clear and noble purpose gave rise to the innovative thinking necessary to get the job done. Improvements in systems, processes, contractual arrangements and technical specifications are some of the concrete legacies that will benefit the people of Christchurch now and for the generations that follow.

It is our hope that this also benefits the country's other urban centres.

7 ACKNOWLEDGEMENTS

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- Christchurch City Council, CERA and the NZTA who instigated the programme of works and provided funding and ongoing support.

- SCIRT who managed the programme.

- City Care Ltd who repaired the leaks.

- Detection Services Ltd and Pure Technologies Pty Ltd who tested the water supply network and found the leaks.