USING HYDRAULIC MODELS TO AID THE EARTHQUAKE RECOVERY

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ABSTRACT

The September 2010 and February 2011 Canterbury earthquakes had a devastating effect on the city of Christchurch and a significant impact on the City's water and wastewater infrastructure. Opus International Consultants were engaged by Christchurch City Council to assess the impact the loss of water supply infrastructure would have on the Central City Water Supply Zone supplying peak summer demand.

Infoworks WS hydraulic models were used to identify shortfalls in the network, to prioritise repairs and identify strategic locations for new well sites as part of the recovery. Operational water supply (zonal) boundaries were reviewed, to assess where additional supplies could be imported to service areas where there were supply deficiencies.

It is now recognised that there is a need and an opportunity to embrace a number of drivers and objectives as a result of lessons learnt from the recent events. The open nature of the current supply regime impeded the response and recovery work, and could be improved by re-zoning the system into smaller management zones.

The key focus of the presentation is to demonstrate the value of having an up to date hydraulic model, how it can be used to support Operations and Planning staff through the recovery period following an emergency event, and to highlight work being carried out to create a more robust, resilient and efficient Christchurch water supply for the future.

KEYWORDS

Water Supply, Earthquake, Hydraulic Modelling, Operations

1 INTRODUCTION

The September 2010 and February 2011 Canterbury earthquakes had a devastating effect on the city of Christchurch and a significant impact on the City's water and wastewater infrastructure. Opus International Consultants were engaged by Christchurch City Council (CCC) to assess the impact the loss of water supply infrastructure would have on the Central City Water Supply Zone supplying peak summer demand.

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The key focus of the presentation is to demonstrate the value of having an up to date hydraulic model, how it can be used to support Operations and Planning staff through the recovery period following an emergency event, and to highlight what is being carried out to create a more robust, resilient and efficient Christchurch water supply for the future.

This paper discusses the challenges that CCC faced during the recovery phase, to provide acceptable levels of services, return operations back to business as normal, to allow operational planning to be carried out with confidence and to identify what could be learnt for the future.

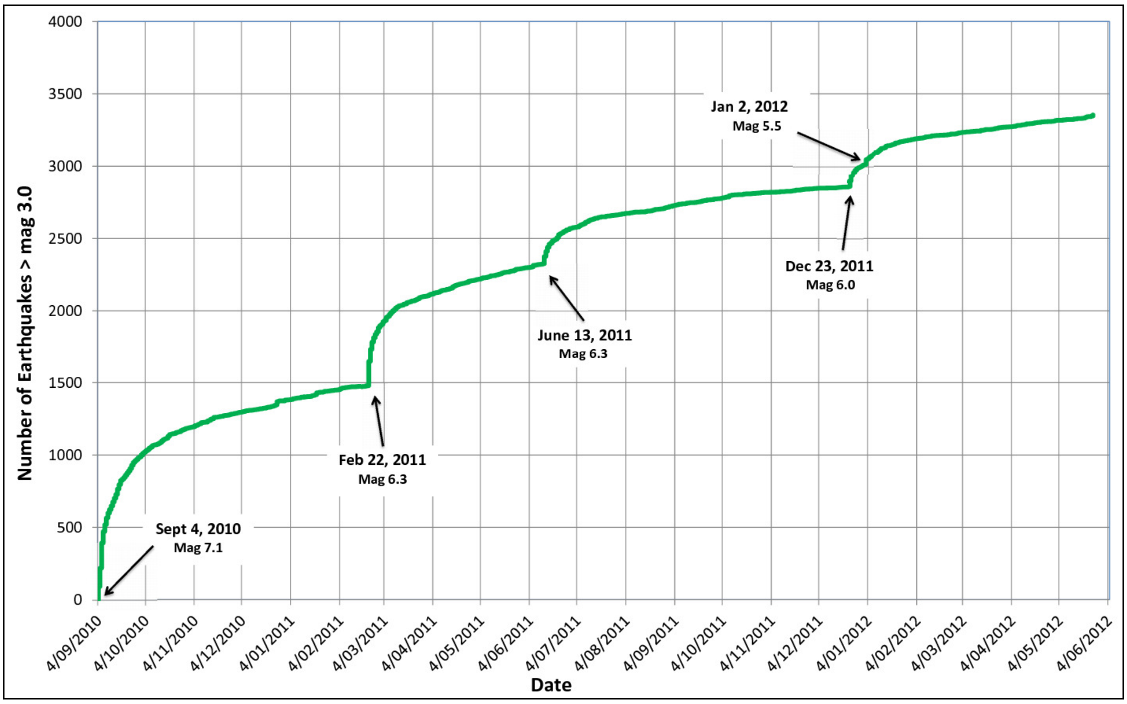
2 THE CHRISTCHURCH EARTHQUAKES

2.1 EARTHQUAKES

The Canterbury region has to-date experienced over 10,000 aftershocks since September 2010, and GNS Scientists have advised that the shakes will continue for years to come. The sequence of events started on the 4th September 2010 with a magnitude 7.1 earthquake centered near Darfield, this was followed with a second major event on 2nd February 2011 with a magnitude 6.3. It was this event, which was shallower and closer to the city that caused most of the damage.

There have since been similar sized events occurring across Christchurch, as the City works to rebuild and repair the damaged infrastructure. Figure 1 shows the significant effect of the February, June and December 2011 earthquakes re-energising the Darfield aftershock sequence from 4th September 2010.

Figure 1: Aftershock Decay Sequence For Canterbury (>Mag 3.0)



2.2 EXTENT OF THE DAMAGE TO WATER INFRASTRUCTURE

The September 2010 earthquake caused significant damage to underground pipelines and wells throughout the water supply network, namely pipe breaks resulting in water loss. Repairs were carried out relatively quickly and water service was restored to the City supply.

The extent of the February 2011 earthquake was felt much greater, through loss of life, damage to buildings, the sheer scale of the event and overall impact on the lives of the Christchurch people. The task to reinstate the water supply was vast, compounded by the continuing aftershocks, damage to the wastewater network, flooding and liquefaction in large areas of the City.

The damage to the water infrastructure can be summarised as follows:

- 150km of water mains likely to require replacement;
- Up to 200km of water sub-mains to be replaced;
- 12 reservoirs need repairs;
- 2 reservoirs need rebuilding, which includes the largest City reservoir (35ML);
- 2 water pump stations to be rebuilt;

- Of the 175 City Wells:
  - Wells with no issues reported: 64
  - Wells repaired to-date: 68
  - Wells yet to be repaired: 18
  - Wells Out of Service to be rehabilitated: 5
  - Wells Out of Service need re-drilling: 20

The damage to the water infrastructure was largely a result of the February earthquake causing extensive damage throughout the City and Hill areas, with the eastern suburbs suffering the most severe damage. Appendix 1 shows the degree of damage to the pump stations, reservoir and pipes across the City water supply.

The net effect of the cumulative damage has resulted in the water supply losing 20% of its capacity to pump water around the City.

The loss of wells was mainly related to damage to well casings. In September 2010 this was caused by an effect known as ‘lateral shear’, where the well casings were distorted (deep) under the surface by the horizontal movement at interfaces between the layers of earth (strata). In both February and June 2011 where the ground movement was more vertical, the well casings were lifted bringing many of the wells out of alignment with the water pipes.

Damage to pump stations was mainly related to the building structure and floor slab (Photograph 1), with most operating but will still need to be fixed at a later date, once structural inspection of all sites and design standards are completed. Palmer’s station in the eastern suburbs was damaged beyond repair and is being rebuilt at a new site.

Similar to the pump stations a number of reservoirs suffered non-critical damage and remain in service. However in the long term remedial works will need to be carried out to bring them back up pre-earthquake condition. The largest reservoir (35ML) in the City’s network, Huntsbury 1 was extensively damaged with all the water being lost through the floor slab in February 2011, shown in Photograph 1.

Photograph 1: Huntsbury 1 Floor Slab and Typical Pump Station Floor Slab Damage

Upper Balmoral reservoir sustained structural damage to the roof and walls, which will require significant repair to wall/beams. The reservoir is currently operating at a reduced water level until such time the repairs can be carried out.

Damage to the water supply mains is estimated to be in excess of 150km.This excludes those areas yet to be properly assessed because the pipes are under roads. The extent of the damage was far less than it may have been a few years ago due to the proactive mains renewal programme already underway by CCC. The estimated burst rate has increased by 250% on 2010 records.

The water supply mains were damaged through cracks, breaks and some joint breakage. The cracked pipe walls resulted in reduced delivery pressure, leakage and sometimes destabilised the ground and/or utility conduits.

A number of older pipe sections completely broke resulting in pipes being turned off or isolated, with temporary services in place until new pipes could be rebuilt. Pipe breaks can also be attributed to joint failure, where the ground movement has caused the two pipe sections to pull-out or alternatively produce over-inserted joints (see Photograph 2).

Photograph 2: Pipe Failures – Joint Pull-Out and Pipe Break

Boil water notices were issued directly to all residents after major earthquake events due to the risk of contamination. This was to allow CCC to carry out water quality sampling to check for contamination. Following the February event during the recovery phase temporary chlorination was introduced at all well sites. However this has since been turned off. The chlorination equipment will remain in place to ensure better response to future emergency events, safeguarding public health.

Naturally the degree of damage to the pipe network has resulted in leakage levels increasing significantly across the City. Analysis has shown that leakage has increased over 40% on pre-earthquake levels. Leak detection and repairs teams were deployed following the September and February events and continue to operate to return leakage levels to pre-earthquake levels.

The overall impact of the loss of wells and pump stations and increased leakage has seriously reduced the City's water supply system's capacity, impacting on its ability to meet summer demands.

3 WATER SUPPLY SYSTEM

3.1 WATER SUPPLY SYSTEM LAYOUT AND OPERATION

The Christchurch Water Supply urban area is based on a system of wells dispersed across the area, which distributes drinking water to customers via pump stations and approximately 3,050km of pipework.

The aquifers that serve as the drinking water source are under pressure, resulting in low pumping costs. In addition the high water quality does not require treatment, resulting in relatively inexpensive water to deliver to customers.

The Christchurch City Water System is sourced from the West-Melton aquifer system, through a total of 175 wells based at 57 primary pump station sites that are evenly located across the city into 1,600km of water mains and 1,450km of sub-mains. The West-Melton aquifer system is recharged through a combination of the Waimakariri River and to a lesser extent, rainfall within the region. Around 50% of groundwater currently extracted from the West-Melton aquifer system is used for public consumption with the remainder being taken from private wells for agricultural and industrial use.

The City is divided up into a number of pressure zones, which were previously generated through old council authorities that formed Christchurch City in 1989 and not on system hydraulics. These water supply zones operate on different pressures that are generally supplied from wells located within their system boundaries. Groundwater is supplied into reticulation either directly through a well pump or firstly into storage/ suction tank before surface pumps supply water into the water system.

There are a number of major reservoirs located in the south of the City in the Hill suburbs which act as storage or balancing tanks for the City and the higher elevated areas. These reservoirs balance on the interconnected pipework resulting in higher than desirable operating pressure across areas of the City. There are also a series of small boosters and reservoirs which have been constructed to meet the increasing demand for properties in the elevated areas in the hills.

The fairly open nature of the supply system with few strategic / bulk water supply mains has resulted in pipework which is generally less than 300mm diameter, with the largest pipes being 600mm.

3.2 CURRENT SYSTEM OPERATION

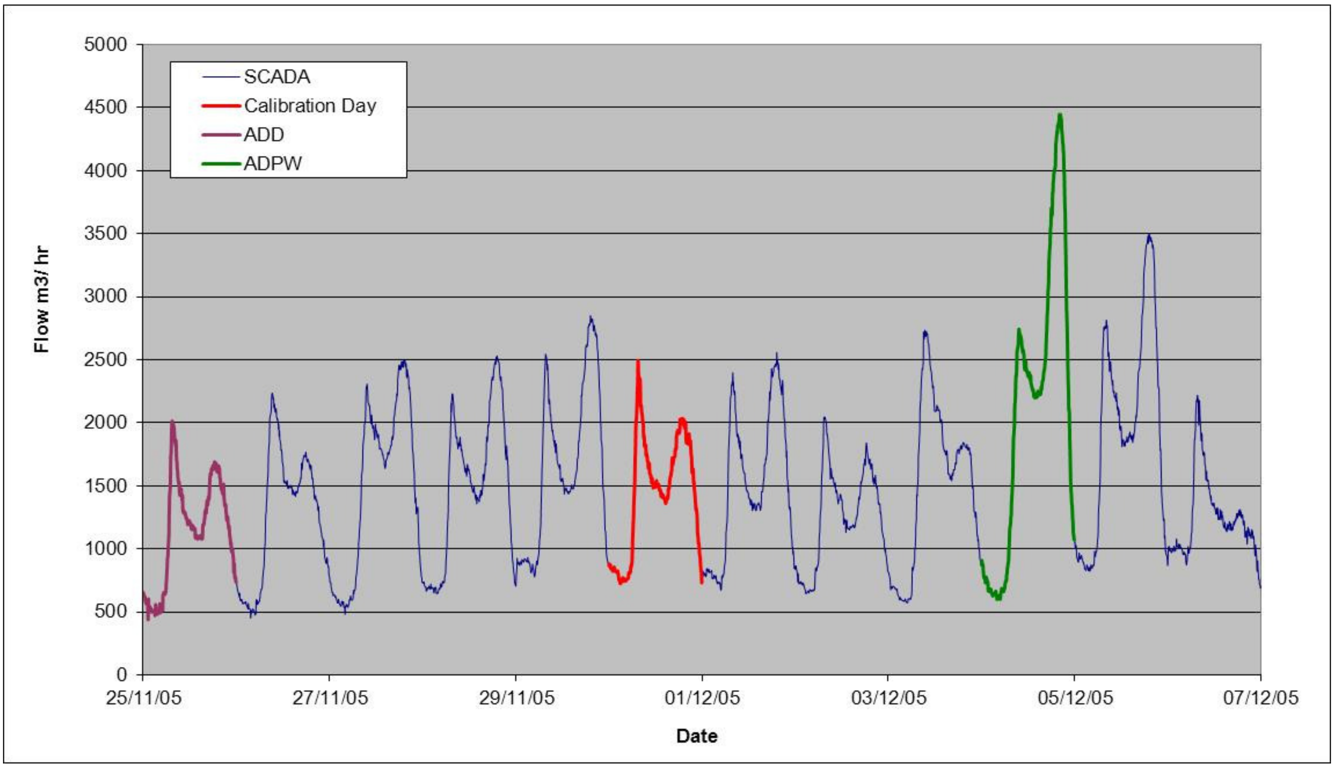
Current system operation is driven by the layout of wells, pumping stations, service reservoirs and supply zone boundaries. The operating strategy has been developed over many years of operating the system, with different operators applying their own minor modifications dependent upon their particular perception, understanding and "tried and trusted" methods. A plan of the Christchurch water supply system is located in Appendix 1.

All pumps are monitored and controlled manually by the main pump controller, direct from the control room located at the Bromley Waste Water Treatment Plant (WWTP) throughout a 24-hour day. The pump operators have not only to maintain individual zone target pressure across the system, but to also ensure the major reservoir levels are maintained, reservoir turnover during peak demand, and to consider the constraints of power demand ripple periods during winter when meeting demand by releasing water from the major reservoirs.

3.3 DEMAND PATTERNS

Christchurch public water consumption is considered to be relatively high. Over the course of a 5-year period the median abstraction rate was 435 litres per person per day (L/per/d).

Figure 2: Fluctuating Demand Pattern Across a 10-Day period for Water Supply Zone



The volume abstracted on any given day fluctuates seasonally and even weekly as demonstrated by the graph shown in Figure 2. The increase in summer demand can be largely attributed to garden irrigation. The summer peak evening hour factor is typically twice an average day morning peak, placing the pumped supply under increased pressure stress to meet peak hour demand.

3.4 MODELLING STRATEGY

A water modelling strategy was developed in 2004 to review CCC's network modelling requirements and to develop a plan to guide future investment to build models of a high standard.

The drivers for the modelling strategy can be summarised as:

- More efficient operation of the system;
- More efficient use of resources;
- Improved level of service to customers;
- Ensure community requirements and legislative obligations are met;
- Ensure the system can sustain population growth and relocation;
- Optimise mains replacement and rehabilitation works by ensuring the most suitable mains size and materials are used; and
- Optimise headworks facilities by ensuring the most suitable pumping and well capacity are located appropriately.

To date CCC has built and calibrated models of their entire water supply network in line with their model build specification using the modelling package InfoWorks WS. The model build specification was developed in accordance with best international practice and internal CCC systems and standards.

4 ANALYSIS

The main objective of the modelling analysis was to assess the impact the loss of well sites and pump stations would have on the Central Water Supply Zone (WSZ), which includes the most significant damaged Eastern suburbs to supply peak summer (2011/12) demand, following the February and June earthquakes and to identify what would be required to meet peak summer demand.

Furthermore the study also assessed the likely impact the earthquake remedial works in the Central WSZ will have on meeting next summer's (2012/13) peak demand and to review leakage levels pre and post-earthquake for all water supply zones.

A consultation approach was adopted due to the relatively changing environment, ongoing aftershocks, condition assessments and urgent/temporary repairs, plus to allow for local knowledge input and network experience.

The team consisted of CCC Network Planning, CCC Pump and Control Staff and Opus water modelling specialists. Meetings were held regularly to upload the most recent information, as this was typically not stored in one place but held in a number of people's heads. The meetings were largely spent in front of the model and updating information and running different scenarios to assess the impact.

A well asset register was provided by CCC detailing the status of each well. This register was considered as a live document, due to the well status changing daily, as a result of the continuing aftershocks, the fragile condition of some wells and well repairs. In summary the number of well sites expected to be out of service for the 2011/12 summer, was a total of 22 wells from the 84 well sites within the Central WSZ.

A flow balance was developed to determine the current available well pump capacity and surface pump capacity versus the peak hour demand, based on the peak day, factoring in the increased water losses through main breaks and the reduction in demand within the CBD zone.

4.1 MODEL UPDATES

The Central WSZ and Ferrymead calibrated *'Average Day Peak Week'* (ADPW) models were used and merged to form one single model. It was decided to look at an extreme demand condition, so the peak day from the previous 5-years was adopted and the models updated to represent the 8th January 2009.

The update required re-calculating and increasing the domestic demand usage, as well as changing all the individual pump start/stop times as recorded in SCADA, as all pumps are manually controlled by the operators in the control room across a 24-hour period.

As the models were built in 2006/07 any new infrastructure since then would not have been represented in the model. Therefore a high level approach was adopted to capture any key infrastructure namely pipework in excess of 200mm diameter and any new wells/pumps.

A list of the closed valves within the Central WSZ including the CBD red zone was provided by CCC and updated into the model to simulate flow paths accurately. The demand within the CBD red zone was removed from the model, as this area was now isolated from the Central zone supply area. The temporary zonal valves, used during the June emergency response were also included as part of the update.

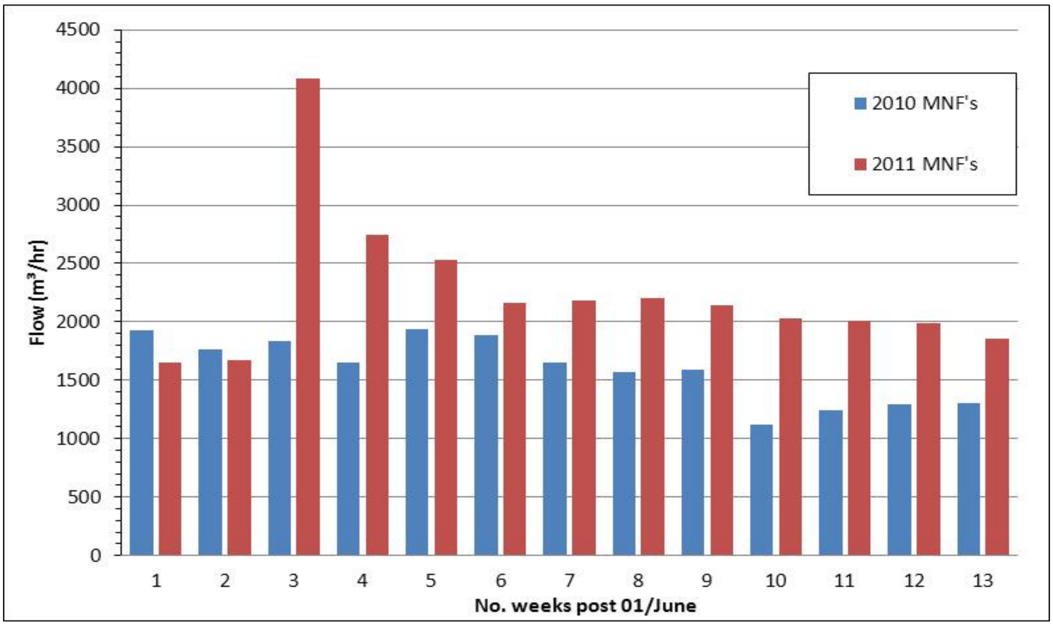
4.2 MINIMUM NIGHT FLOW ANALYSIS

Minimum night flow (MNF) analysis was also carried out for each of the WSZs, pre-earthquakes (June to August 2010) and post-earthquakes (June to August 2011) to determine current levels of leakage and to assess the impact active leakage control (ALC) and the repairs have had on returning to pre-earthquake levels.

The Central WSZ is the largest WSZ in the Christchurch water supply network accounting for approximately 60% of all customers and infrastructure, including the CBD and a majority of the worst affected earthquakes areas.

Figure 3 shows the average weekly MNF values for the Central WSZ for 2010 and 2011. The data shows that the pre-earthquake figure was approximately 1,240 m³/hr compared to a post-earthquake figure of 1,940 m³/hr, an increase of 700 m³/hr.

Figure 3: Central Water Supply Zone MNF



Leakage levels have increased extensively across the City, with an increase of 43% across the Central WSZ and up to 675% within some areas of the Central WSZ, based on the MNF sub-zone monitoring. It is clear that the continuing earthquakes/aftershocks are impacting on the condition of the water infrastructure and leakage rates are increasing. The best approach to reducing leakage needs to be managed as each zone will vary depending on a number of factors. For the Central WSZ pressure management may be the most economical approach as opposed to repairing and replacing assets. Caution will need to be applied to some areas where pressure management is proposed to ensure that areas are not being covered up temporarily. This is to avoid mains being replaced and streets being dug up in 5 years' time after remedial works have been carried out, i.e. repairs are carried out before street landscaping in areas like the CBD.

The CBD and areas classified as Red Zones will also need to be factored into the planning for summer 2012/13 such as the type of activity operating within these zones, limited business activity and contractors working on the rebuild. Consideration needs to be given to what happens to abandoned areas with trunk/distribution mains running through them and also how infrastructure is to be managed as leakage levels are likely to be higher, particularly with heavy machinery operating within these areas.

Considerations should also be given to the size of the peak day occurring in summer 2012/13 in comparison to historical periods, as the demand conditions are continuing to change. The number of properties that are now vacant or have suffered land damage should see a reduction in the number of properties irrigating and therefore a reduction in peak day consumption.

4.3 ANALYSIS FOLLOWING FEBRUARY AND JUNE EARTHQUAKES

A number of scenarios were considered as part of the model analysis, starting with the current situation and focusing on the remedial works. This section of the paper presents the findings from the analysis.

4.3.1 ASSESS THE IMPACT THE LOSS OF INFRASTRUCTURE HAS ON SYSTEM PERFORMANCE FOR A PEAK DAY

The loss of 22 wells and a reduced pump capacity has a detrimental effect on the ability to meet peak hour demand within the Central WSZ. The surface pump capacity, based on available well supply is reduced by 3,110 m³/hr to 7,790 m³/hr. The loss of the pumps stations results in a pump to demand deficit of 2,650 m³/hr, as summarised in Table 1.

Table 1: Supply and Demand Scenario for Peak Day 2011/12

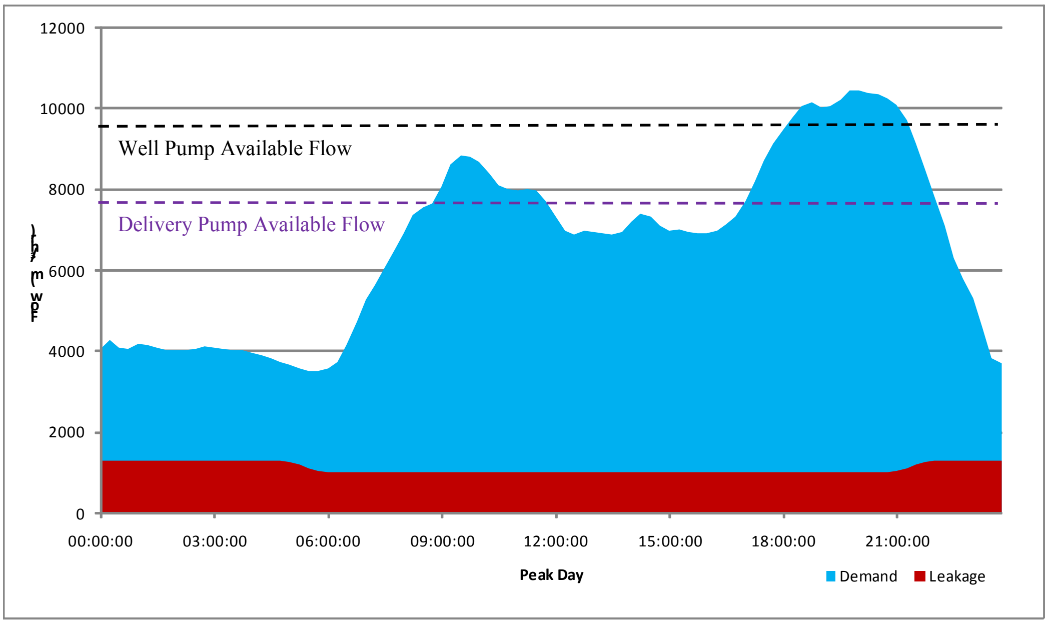
Central WSZ	**2011/12 Demand (m^3/hr)**
Well Pump Available Flow Rate *(excluding wells out of service)*	9,495
Delivery Pump Available Flow Rate *(excluding wells out of service)*	7,790
Estimated 2011 Instantaneous Peak Hour Flow *(increased leakage by 43%)*	10,440
Supply to Demand Peak Flow Deficit	2,650
2009 Peak Day Demand	6,674 (160 ML/d)

The Central WSZ currently did not have sufficient well/pump capacity to meet peak hour demand, due to the sustained damaged to a number of well sites and the loss of Huntsbury 1 reservoir, as summarised in Table 1.

It was clearly evident that additional wells and surface pumps would be required to meet peak hour demand. It was also recommended that city wide water restrictions be used in conjunction with any new well sites to maximise the use of any additional flow.

The shortfall in supply versus demand is shown more clearly in Figure 4.

Figure 4: Estimated Central WSZ Peak Day Demand v Current Available Pump Capacity



4.3.2 REVIEW THE SYSTEM PERFORMANCE WITH THE ADDITION OF NEW WELL SITES AND WITH THE INCLUSION OF ST JOHN'S WITHIN THE CENTRAL ZONE

The next stage of discussions with CCC staff identified a number of preferred locations for new well sites, where key wells were damaged beyond repair. Existing sites where there was spare well capacity, but not available surface pump capacity to deliver it to the network were also considered.

The new well sites and surface pump upgrades that were proposed and subsequently updated into the model for analysis are presented in Table 2.

Table 2: Supply and Demand Scenario for Peak Day 2011/12

Location	**Well**	**Surface Pump**
Hillmorton	Well 5 – 140 m³/hr	Pump 2 - 225 m³/hr
Lake Terrace	Well 3 – 315 m³/hr	
Sydenham	Well 7 – 125 m³/hr Well 8 – 125 m³/hr	
Trafalgar		Pump 2 - 225 m³/hr
St John's	Well 3 – 175 m³/hr	
Keyes Road	Well 1 – 225 m³/hr	
Total	1,105 m³/hr	450 m³/hr

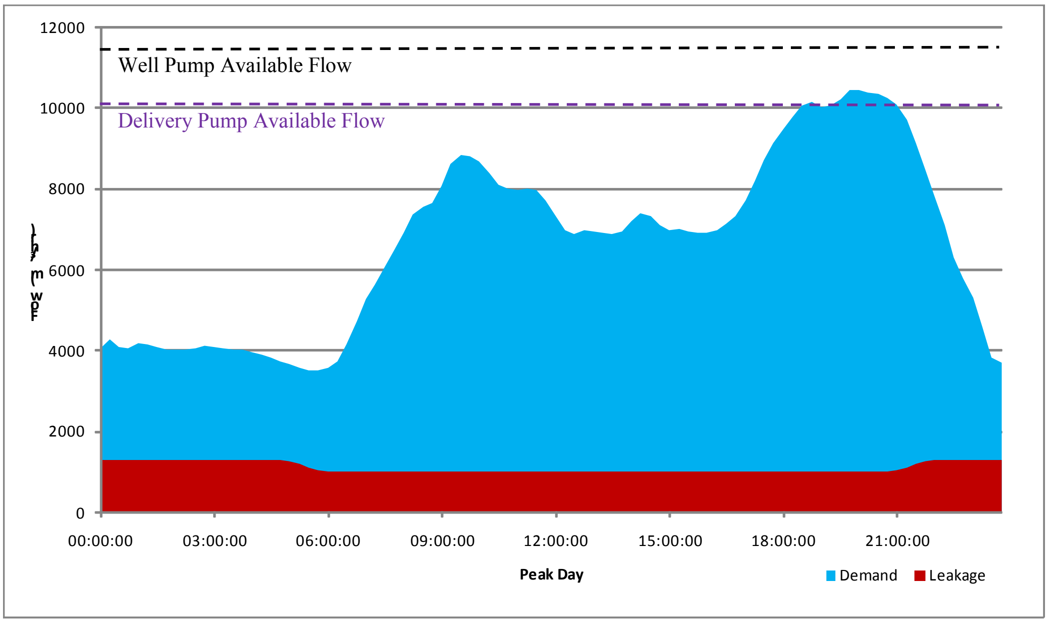
The new well sites provide an additional 1,105 m³/hr of well capacity and 450 m³/hr of surface pump capacity. With the addition of St John's within the Central WSZ and the increased well/surface pump capacity the available delivery pump flow is 9,722 m³/hr, an increase of 1,932 m³/hr.

Table 3: Supply and Demand Scenario for Peak Day 2011/12 with New Infrastructure

Central WSZ – Inclusion of new wells/pumps	**2011 Demand (m^3/hr)**
Well Pump Available Flow Rate – Inclusion of new wells *(excluding wells out of service)*	11,270
Delivery Pump Available Flow Rate – Inclusion of new pumps *(excluding wells out of service)*	9,722
Estimated 2011 Instantaneous Peak Hour Flow *(increased leakage by 43%)*	10,440
Supply to Demand Peak Flow Deficit	718
2009 Peak Day Demand	6,674 (160 ML/d)

The increased pump capacity with the addition of St John's pump station and new wells is shown more clearly in Figure 5.

Figure 5: Estimated Central WSZ Peak Day Demand v Proposed Pump Capacity



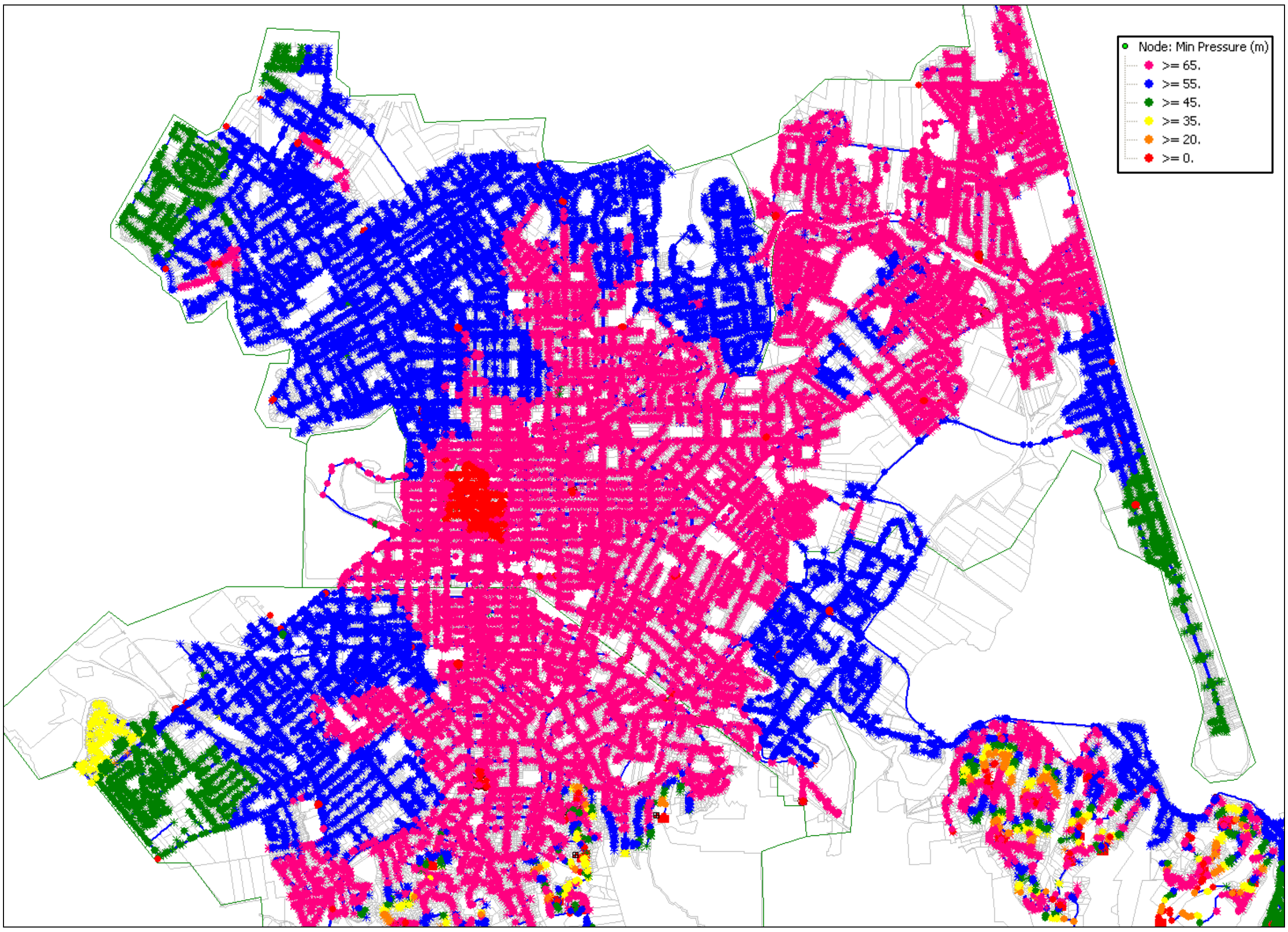
The addition of new wells at Lake Terrace, Hillmorton, Sydenham (2), St John's and a new well site at Keyes Road are not sufficient alone to meet peak hour demand, assuming that all other pump stations are also available. However these new well sites will improve levels of service within a number of areas, particularly the eastern suburbs. The new well at Lake Terrace and a new well direct into supply at Keyes Road, are critical to ensuring managing well and pump capacity during peak hour conditions..

In addition to the well sites listed above, efforts should also be concentrated on Averil, Hills and Estuary pump stations, to repair existing wells or drill new wells. Improving the current well capacity at these stations will strengthen the overall network and improve pressure within the localised areas.

The introduction of the new wells and supply from St John's (Ferrymead WSZ) significantly improves the ability to meet peak hour demand, with the inclusion of water restrictions. Consideration should be given to the likelihood of a peak day occurring this summer as the demand conditions have changed. The number of properties that are now vacant or have suffered land damage should see a reduction in the number of properties irrigating and therefore a typical peak day occurring.

Figure 6 shows the peak hour pressure across the Central WSZ with the inclusion of the new wells. A number of delivery pumps are running off their curves in order to meet the peak hour demand, which is why the pressure drops in a number of locations, namely at the extent of the network.

Figure 6: Peak Hour Pressure



4.3.3 NEW HUNTSBURY RESERVOIR

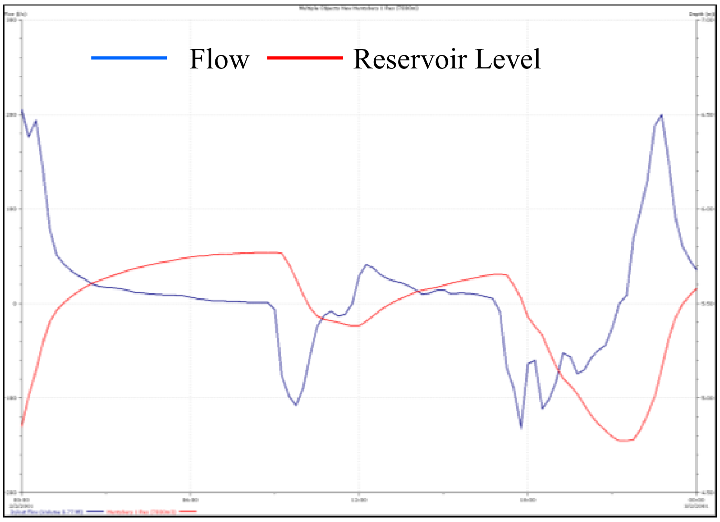
The Huntsbury 1 reservoir sustained extensive structural damage to the floor slab and internal walls following the February earthquake, and as a result would need to be rebuilt. The Huntsbury 1 reservoir is considered a critical site, as it plays a major role in meeting peak hour demands during the summer and also during winter periods when diesel pumps are used to manage electricity tariffs during a ripple period.

The modelling was used to help justify the need to advance the rebuild of a new reservoir at the current Huntsbury 1 site before summer 2011/12 and also to review the current Huntsbury 1 booster station location, with respect to assessing the merits of changing the elevation of the pumps by moving it down the hill so it could operate of City mains pressure, as opposed to the current set-up off the reservoir.

A new 6,500 m³ capacity reservoir at the existing Huntsbury 1 site will assist with managing peak hour flow and also provide strategic storage for the hillside areas and allow the Huntsbury 1 booster station to operate.

Figure 7 shows the new Huntsbury 1 reservoir depth and in/outflow for the peak day. During the peak hour the reservoir provides approximately 100 L/s into the network, the equivalent of two new wells.

Figure 7: New Huntsbury Reservoir In/Outflow and Depth



4.3.4 WATER RESTRICTIONS

For the past summer 2011/12 it was highly recommended that city wide water restrictions be implemented in conjunction with any new well sites, to maximise the availability of water.

The target levels for restrictions allow for some redundancy in the network to factor in risk where wells or pumps are not available during the peak day/hour. To assess the staging of restrictions, trigger levels need to be established. As the peak hour demand is the governing factor, it was proposed that either a maximum peak hour trigger level is established or maximum usage per property/person per day.

It was recommended that Low level restrictions be applied from the 1st October, allowing residential customers to irrigate on selected days with no irrigation on Mondays, as highlighted in Table 4.

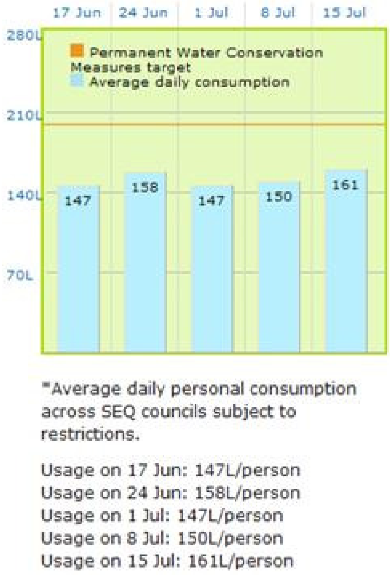
Table 4: Proposed Water Restriction Levels

Restriction Level	Trigger Level	Requirements
1	From 1st September through to 31st March	No irrigation on Monday's Even Property no. – Tuesday, Thursday, Saturday Odd Property no. – Wednesday, Friday, Sunday
2	Peak hour > 8,200 m³/hr	Hand held water use only on selected days as per Low Level.
3	Peak hour > 9,200 m³/hr	No outdoor water use – Total hosing ban

It was recommended that a review of the summer daily demands from 2010 against previous years be carried out to determine acceptable peak hour trigger levels.

A similar approach, as adopted in Australia could be used to promote and educate on water conservation to the public, using the local press and CCC website to publish daily water use and target levels. South-East Queensland currently has permanent targets in place 'Target 200', where residents are encouraged to continue to use less than 200 L/person/day. The graph shown in Figure 8 is updated weekly and summarises the average residential usage per week.

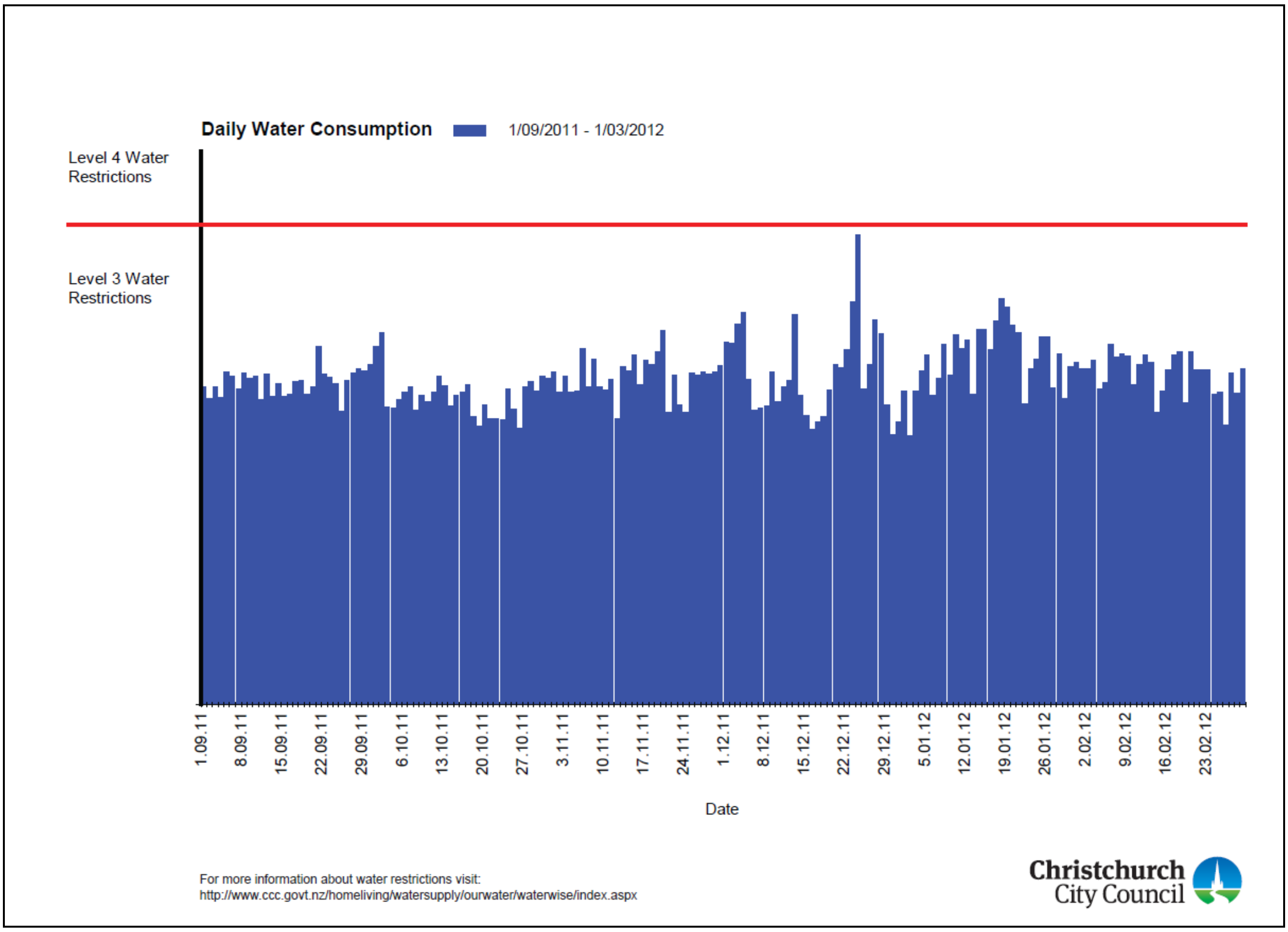
Figure 8: SEQ Residential Consumption Tracking



5 OUTCOME

Level two water restrictions were introduced by CCC on 8th October 2011 and ended on 2nd April 2012. Figure 9 clearly shows that the water restrictions played an integral role in managing water use, as well having a reasonable wet summer, ensuring there was sufficient pump capacity to meet peak hour demand.

Figure 9: CCC Daily Water Consumption – Summer 2011/12



Consumption is down by approximately 18 million litres per day, equivalent to seven Olympic sized pools compared to normal summertime peak use. The reduction in demand has allowed customer level of service to be maintained provide adequate pressure for firefighting.

The new Huntsbury 6,500m³ capacity reservoir was completed under 3-months and commissioned before Christmas 2011 along with a new booster station for the elevated Hill zones. The reservoir can provide the equivalent of two additional wells into the system, supplying approximately 360,000 litres per hour.

Stage 2 of the Huntsbury reservoir is now under way for a second 7,000 m³ tank on the existing Huntsbury site, with the middle of the existing reservoir being demolished to create a flat grassed area between the reservoirs.

Palmer's pump station was damaged beyond repair following the September 2010 earthquake and is set to be demolished. This leaves the New Brighton area and eastern suburbs without sufficient pump capacity for peak demand. The modelling confirmed that the Rawhiti Domain would be an ideal location for a new pump station to service the eastern suburbs as its more central location will help to improve resilience to the network and particularly in the event of a failure of the Bexley pump station which sustained earthquake damage.

Two new wells have been drilled to-date at the Keyes Road site with a further two wells planned along with a suction tank, pump house to locate the surface pumps to transfer the water into the network and a generator for power outages.

Seven new wells have been drilled since June 2011 and a number of new wells and existing wells are currently being drilled or re-established. The Stronger Christchurch Infrastructure Rebuild Team (SCIRT) is making steady progress on the rebuild programme and to date 18.6km of water supply pipe has been laid.

The repairs to existing wells and the planned new wells across the Central WSZ will provide sufficient well/pump capacity to meet predicted peak hour demand for 2012-2013 summer high demand period.

The inclusion of the new wells is critical to ensuring that peak hour demand can be supplied and for water restrictions to be avoided next summer. Ensuring that existing repaired wells/pump stations stay in service is equally as important. The inclusion of two new reservoirs at Huntsbury 1 will also provide additional capacity to meet peak hour demand.

6 CONCLUSIONS

Having a tool that is fit for purpose installs confidence in not only the user but those that are reliant on the output i.e. operations and planning. In the case of CCC they have invested heavily in their hydraulic models, firstly through the implementation of a modelling strategy, secondly from the development of a model build specification to improve quality and consistency and finally to building and calibrating models of their entire water supply.

In recent years the operators of Christchurch water supply have had a greater exposure to their water models and have understood the value in having an up to-date robust tool that represents the water network and operation. This has allowed the Operations team to use the models to look at what-if scenarios and assess the impact that changing the pump operation, reservoir set-points, modifying operational boundaries will have on system performance. In most cases this has installed confidence to allow the changes to be made in the system, with great success and furthermore opens up people to change, or challenges why the system is operated in a certain way.

Following the Christchurch earthquakes the Christchurch water models were used to good effect to assess the impact the loss of key infrastructure would have on meeting summer demand, to identify where the best location for repairs/new wells sites would be, and to assess the ultimate impact this would have in meeting summer demands now and in the immediate future. The models were an invaluable tool during the Christchurch recovery phase, and allowed informed planning decisions to be made that otherwise could not have been made with confidence.

The outcome from the modelling highlighted that a number of approaches were required to minimise the impact the loss of wells sites and reservoir would have on peak summer demand. Repairing well sites, in conjunction with a new reservoir at Huntsbury and water restrictions were required, which proved successful as a full watering ban was not implemented during summer 2011/12 and consumption was well down compared to normal summer periods.

CCC operations were able to make immediate changes to the network based on the outputs of the modelling, as the modelling analysis provided confidence that operational changes would work in reality. This included opening the operational boundary between the Central and Ferrymead WSZs, modifying reservoir set-points and changing the operational status of pumps to utilise any redundancy in well/pump capacity.

The modelling has also looked at the short term planning needs to supply next summer's peak demand and to eradicate the need to impose water restrictions. This has allowed CCC to focus their efforts in the right areas to ensure that the necessary repairs to wells, pump stations and reservoirs in addition to new planned infrastructure are carried out in good time to achieve this target.

The water supply models are also being used to support SCIRT and CCC on the water supply renewals, in particular where upgrades or 'betterment' would be beneficial to improve current levels of service for areas where pipes are under capacity i.e. fire flow.

The earthquakes of September 2010, February 2011 and June 2011 highlighted a number of issues related to the open nature of the current supply regime that impeded the response and recovery work and could be improved by re-zoning the system into smaller management zones. Smaller zones would result in parts of the system being restored more quickly through a staged recovery plan, effectively getting most areas back to full operation quickly and isolating more badly damaged areas and then focusing resources in these areas. As an interim measure, operations staff have closed a number of smaller pipes, limiting the number of valves needing to be closed after a future event. This will certainly help restore supply more efficiently where pipes are under capacity as this is a one-off opportunity.

A recent project has been undertaken to investigate the potential for re-zoning the water supply and build a business case around the significant potential gains, such as achieving better pressure management, reduced operating cost, and emergency response, extended asset life and reducing overall water consumption. The hydraulic models are currently being used as an integral part of this project to establish the operational boundaries and assess the impact the rezoning and pressure management will have on current system performance.

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REFERENCES

GNS Science, (2012) 'Map showing earthquakes together with aftershocks above magnitude 3 and fault ruptures in Canterbury'

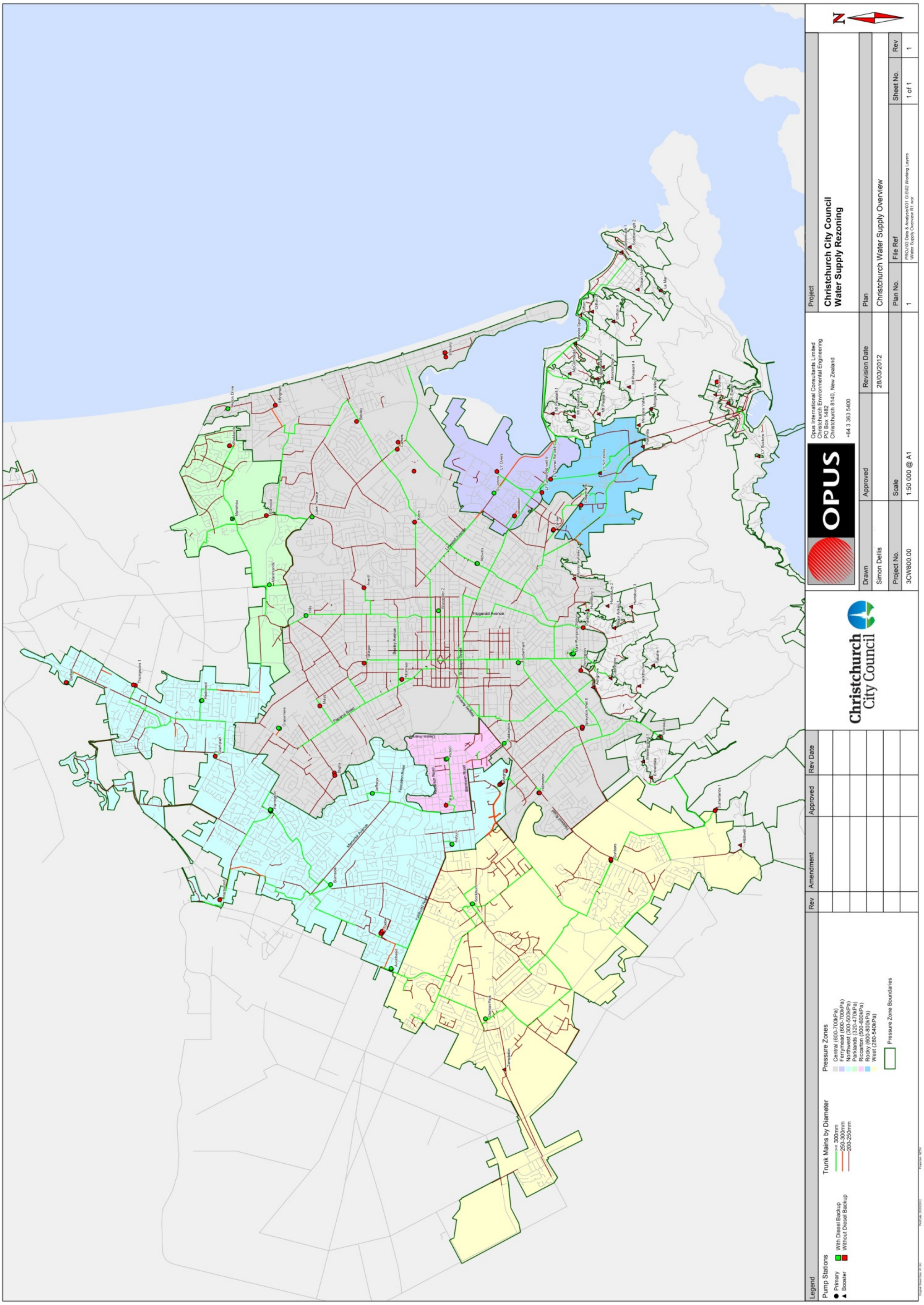
GNS Science (provided by Chris Mance), (2012) 'Graph showing the significant effect of the February, June and December 2011 earthquakes re-energising the Darfield aftershock sequence'.

J Black, (2012) 'Earthquake Damage to Buried Pipelines'

Christchurch City Council, (2012) 'Water Restrictions – Daily Water Consumption'

SCIRT, (2012) 'Map showing the extent of water supply infrastructure damage'

APPENDIX 1 – CHRISTCHURCH WATER SUPPLY SYSTEM



APPENDIX 2 – WATER SUPPLY INFRASTRUCTURE DAMAGE