INNOVATIVE APPROACH TO FIRE FLOW ASSESSMENT FOR THE CHRISTCHURCH WATER SUPPLY REZONING

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ABSTRACT

The Christchurch Water Supply Rezoning project involves changing zone boundaries and pressures for many of the large water supply zones of the Christchurch water supply. The Christchurch earthquakes highlighted the vulnerability of large water supply zones. Changes to the water supply zones offer an opportunity to improve resilience of the system, as well as extend asset life through pressure management and reduce operating expenses.

A key part of the project was assessing the effect of the changes on fire flow compliance. Assessing fire flow requirements and available fire flow for an entire city in detail would be prohibitively expensive, so a number of innovative approaches were developed to simplify the assessment processes. The processes included ways of using the available GIS data from Christchurch City Council to estimate the required fire flow for each land parcel in the city, and to assess the likely capacity of multiple hydrants in the vicinity of each land parcel.

The processes developed provide a practical approach to carrying out a fire flow compliance assessment across a whole zone or city in order to identify locations where further investigation to resolve deficiencies could be carried out. This approach could be applied to most water supplies across New Zealand where assessing fire flow compliance is important.

KEYWORDS

Fire flow compliance, pressure management, Christchurch Earthquake, modeling.

1 INTRODUCTION

The Christchurch water supply currently consists of seven water supply zones, with the Central Zone covering most of the city (Figure 1). The Central Zone operates at high pressures to match the large reservoirs located in the hills to the south of the city. The current zoning was largely developed around historical political boundaries, and potential changes had been considered for some time.

The Christchurch earthquakes caused significant damage to the water supply infrastructure for Christchurch. The re-establishment of water supply was more difficult within the Central Zone, due to the scale of the zone.

The Christchurch Rezoning Project was developed to adjust the zone boundaries of the water supply zones to improve disaster resilience, improve zone operation, and allow targeted pressure management to improve asset lives and reduce operating expenses.

A key consideration for Christchurch City Council in making changes to the zone configuration, and introducing pressure management, was the effects on fire flow. Pressure management would only be appropriate if the effects on fire compliance could be appropriately managed, both for flows from hydrants and for fire sprinkler systems.

This paper examines the innovative approaches employed on the Christchurch Rezoning Project to assess the effect on fire compliance, and how these approaches could be used for other communities to assess fire compliance on a city-wide basis.

2 CHRISTCHURCH REZONING

The Christchurch Water supply is divided into seven zones, with many of the zone boundaries based on old political boundaries before the 1989 amalgamation. Average pressures within the zones range from 30 m in the Northwest Zone to 75 m in the Central Zone. The Central Zone dominates the Christchurch water supply and covers approximately two thirds of the city. Significant opportunities for pressure management exist within the Central Zone.

The Christchurch earthquakes, particularly the major earthquakes in February 2011 and June 2011, caused significant damage to the water supply infrastructure for Christchurch. The damage included breaks in pipework, liquefaction entering pipes, damage to wells, reservoirs and pumps, as well as interruption to electricity. The re-establishment of water supply was found to be much more difficult within the Central Zone, in part due to the scale of the zone.

The earthquakes provided a demonstration of the resilience benefits of smaller water supply zones, and the benefits to resilience combined with asset management benefits associated with pressure management provided the basis for initiating a project to re-design the water supply zoning.

The Christchurch Rezoning Project has a number of key design criteria:

- Pump capacity in each zone to deal with peak demand and growth
- Make use of reservoirs where available
- Improve resilience
- Acceptable operation during low, average and high demand, and with diesel pump operation
- Provide a suitable implementation approach
- Avoid creating security of supply issues
- Avoid creating fire flow compliance issues
- Suitable payback period for upgrades required

The first phase of the project has been completed and provisional layouts of new zones have been proposed. More detailed design work is being carried out at present, with a pilot zone planned to be set up this year. The current water supply zoning is shown in Figure 1 and the proposed water supply zoning is shown in Figure 2.

Fire flow compliance is a critical consideration for the Christchurch Rezoning, as any reduction in pressure has the potential to create new non-compliance issues with fire flow, both for hydrant flows and for the operation of sprinkler systems. The focus of this paper is how fire flow issues have been identified and assessed as part of the rezoning project.

Figure 1: Current Water Supply Zoning

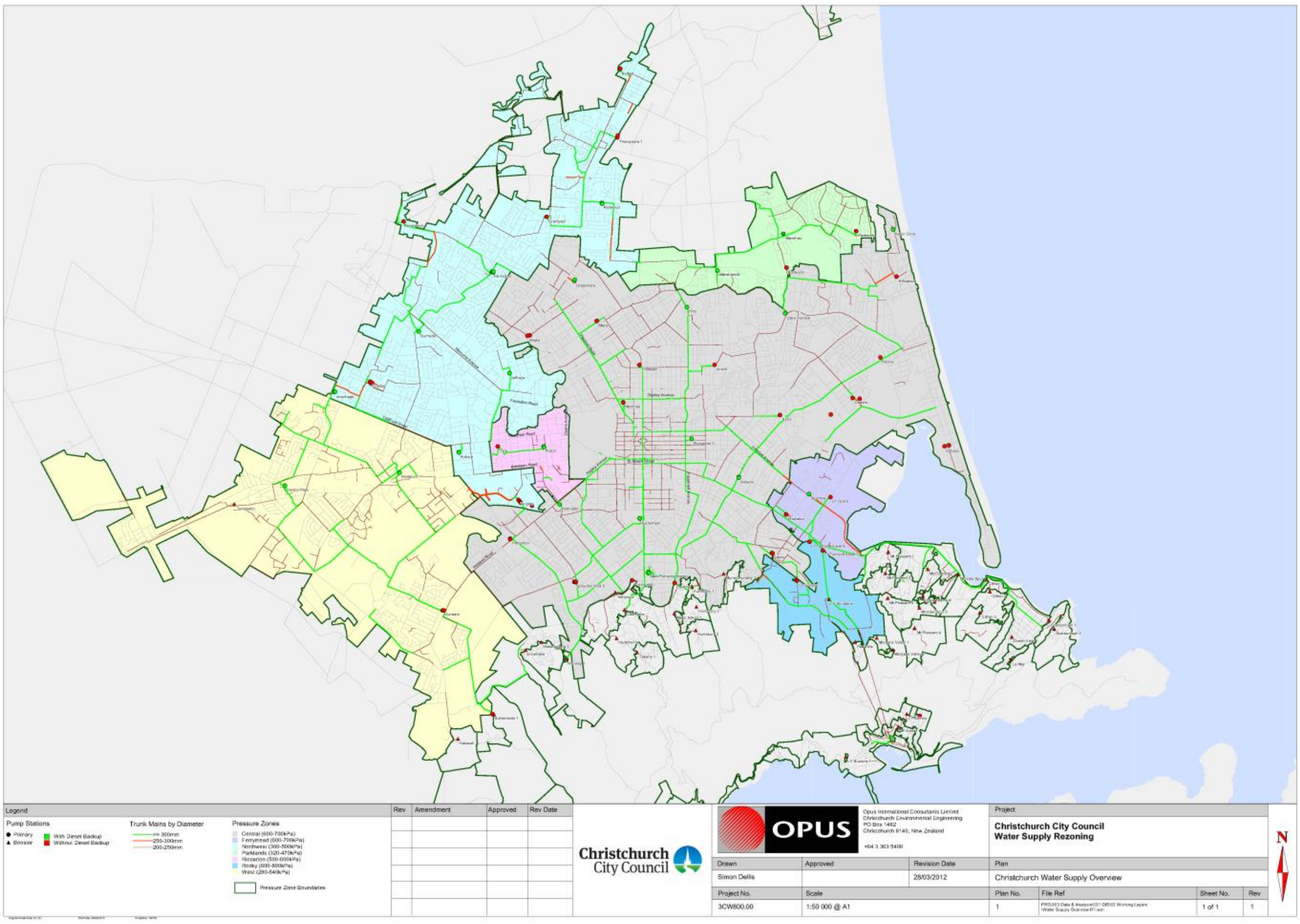
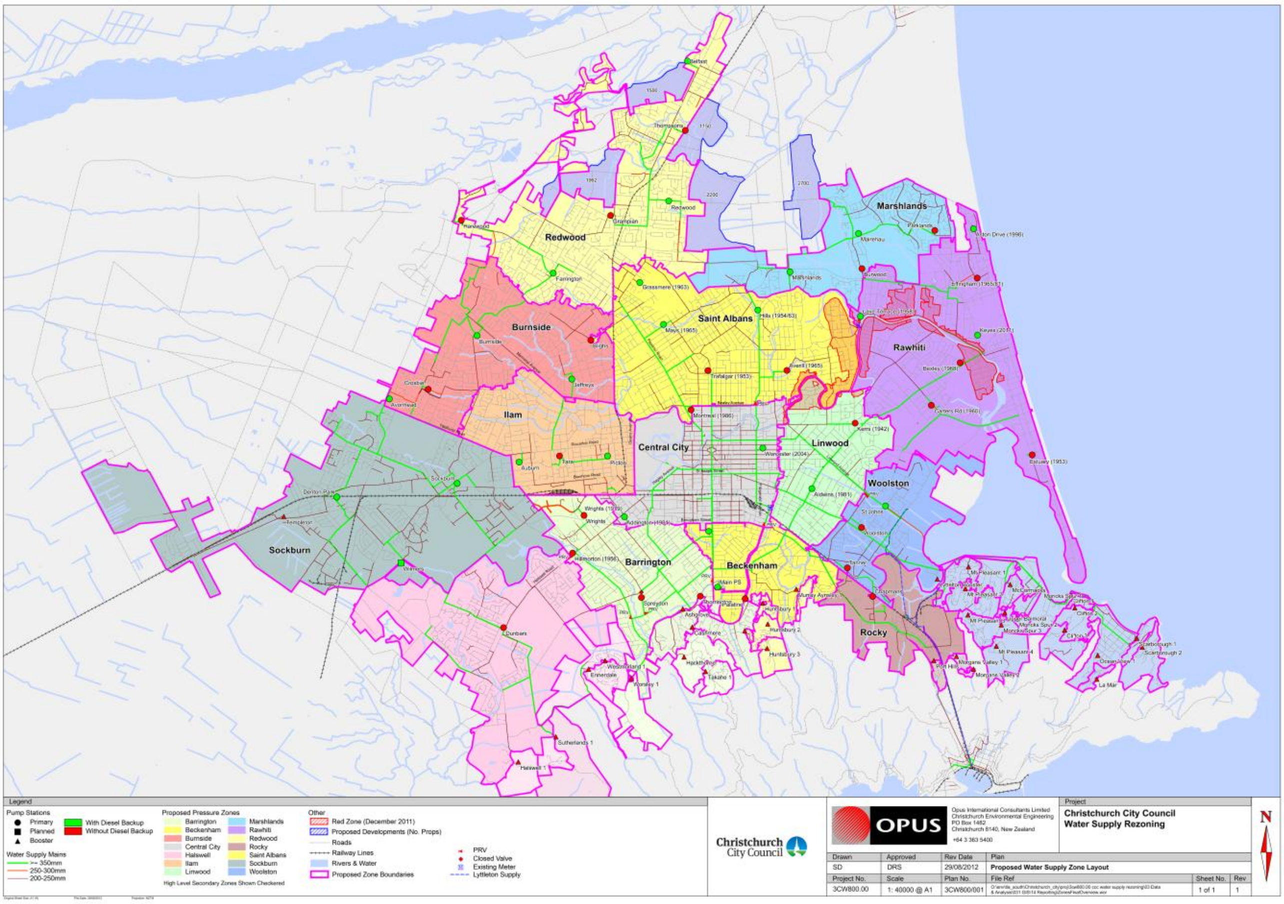


Figure 2: Proposed Water Supply Zoning



3 REQUIRED HYDRANT FIRE FLOWS

3.1 REQUIREMENTS OF CODE OF PRACTICE

The main guidance document for fire flow in New Zealand is SNZ PAS 4509:2008 New Zealand Fire Service Firefighting Water Supplies Code of Practice. The Code of Practice is not mandatory, but most local authorities, including Christchurch City Council, refer to the Code of Practice in their level of service requirements for fire fighting.

The Code of Practice recommends fire fighting flows from 12.5 L/s for sprinklered family homes, to 200 L/s for large or high risk industrial buildings. Particularly high risk structures may require a calculation to estimate the required fire fighting flow, which could potentially exceed 200 L/s (Standards New Zealand 2008).

The Code of Practice is difficult to fully comply with, and most water supplies in New Zealand would not fully comply.

3.1.1 2008 CODE OF PRACTICE

The 2008 Code of Practice is the current version. The Code of Practice is based on assessing each individual fire hazard. The assessment of water supply classification for a building requires information on the type of structure, the nature of activities in the building, the size of the largest fire cell, and whether the building has an approved sprinkler system.

To assess the water supply classification for a single commercial building might take two hours of a fire engineer's time. The Christchurch CBD, before the earthquakes, had approximately 3,750 buildings, so the cost to assess fire requirements in detail across Christchurch would be a multi-million dollar exercise, and was not practical within the scope of the Christchurch Rezoning Project.

In order to broadly identify potential compliance issues within the city, and therefore the effects of the rezoning, it was necessary to produce some form of simplified assessment of required fire flow.

3.1.2 1992 CODE OF PRACTICE

A previous fire flow study for the Auckland CBD (Opus 2006) had been carried out based on the 1992 Code of Practice, which was zoning based rather than the individual hazard basis of the current Code of Practice.

Using a zoning basis is considerably easier than an individual hazard basis for an analysis of a whole city, but using this approach would wrongly classify many buildings to the current Code of Practice, and other differences between the documents would not be taken into account.

Therefore, the 1992 Code of Practice was not appropriate and an alternative approach was developed.

3.2 ALTERNATIVE ASSESSMENT APPROACH

The alternative approach was to develop a consistent series of assumptions, so that where data was not available for an individual building, a sensible assessment of the water supply classification for that particular building could be made.

Land zoning was used to identify family homes, and if no other information was available, to estimate the fire hazard category for commercial or industrial buildings. Christchurch City Council had building plan areas available, which were used as an estimate of fire cell areas, if no fire cell data was available. If floor area and fire cell area were unavailable, an assumed fire cell size was made based on land zoning.

Automated fire sprinkler systems were identified, which allowed the data to be further refined.

The initial results of the assessment indicated a number of buildings in suburban Christchurch might need high fire flows. Further investigation of these buildings indicated that most were schools, hospitals or rest home facilities. Facilities of this nature will generally have multiple fire cells within the buildings, so the facilities were reclassified based on school population, or whether the buildings were multiple storey or single storey.

The simplified assessment process was a practical way of carrying out a fire flow assessment on a city wide basis. The process is not perfect, and will over-estimate the required fire flows for many buildings, as fire cell information was generally not available. In some locations required fire flows will have been under-estimated as fire hazard categories may be incorrect, or multiple storey buildings could have a fire cell area larger than their plan area. The process is appropriate for the Christchurch Rezoning, to broadly assess the potential of pressure management on fire compliance, and would be a useful first step for assessing other water supplies.

3.3 USE OF GIS

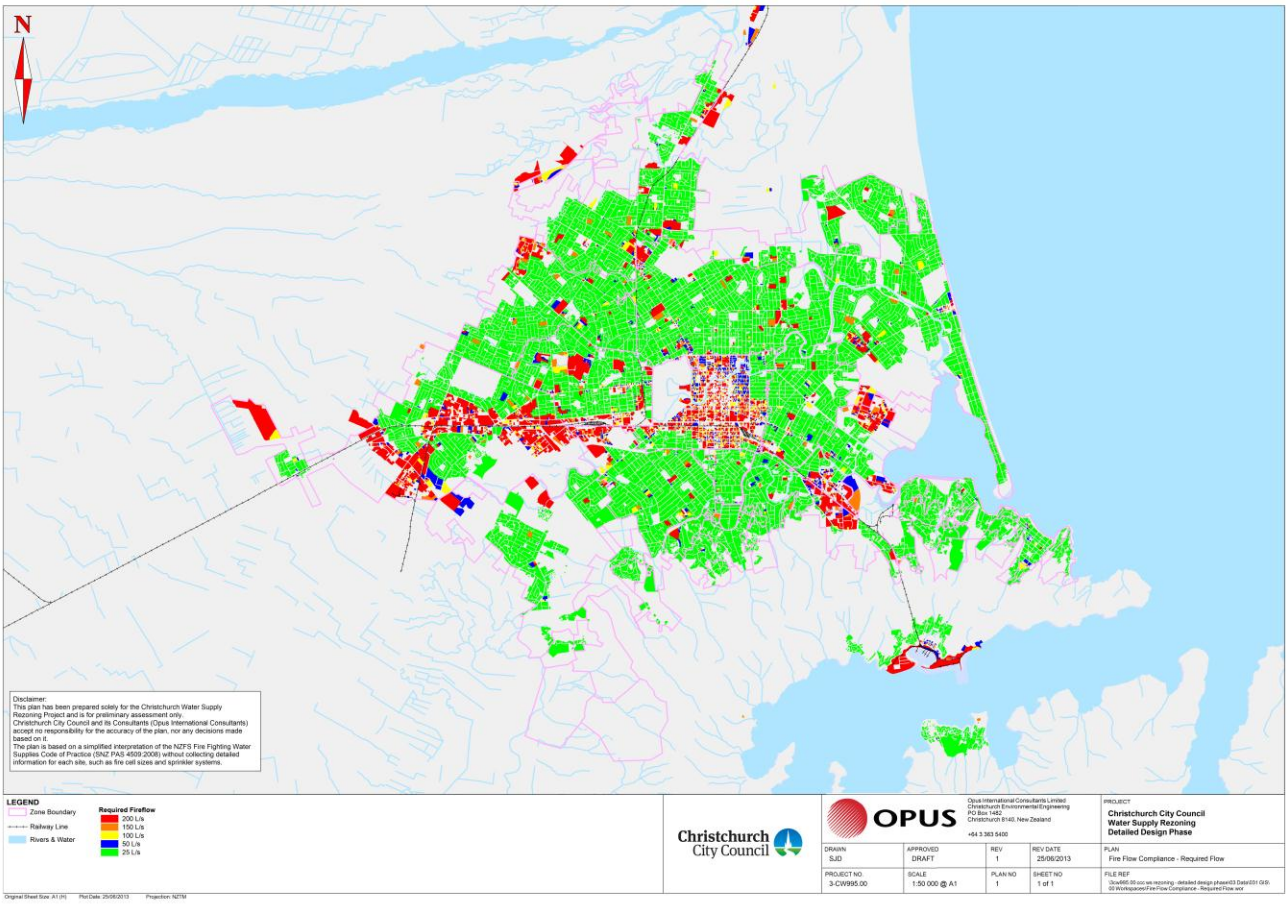
GIS analysis was used extensively in the assessment of required fire flows. The large amount of data involved, and the benefits in understanding resulting from spatially mapping the results meant that GIS was an important part of the assessment process.

Data was provided by Christchurch City Council on land zoning and building areas in a geo-referenced form. The building areas were matched to land parcels, and the area of the largest building on each land parcel was used for the first part of the assessment process.

Sprinkler system data was provided in a spreadsheet form, and address matching was used to attribute the sprinkler systems to the appropriate buildings and land parcels. A similar approach was used to incorporate the schools, hospitals and rest homes to the assessment process.

An important aspect of the approach using GIS was to use the best data that was available at the time, and have the flexibility to refine the assessment if new data became available. The fire flow requirements for Christchurch are shown in Figure 3.

Figure 3: Modeled Fire Flow Requirements



4 AVAILABLE HYDRANT FIRE FLOWS

Once the demand for fire flows has been estimated, the second part of assessing fire compliance is to estimate the available fire flow throughout the network.

Christchurch City Council has a set of calibrated models covering each of the water supply zones, which were used to assess the available fire flow.

Modeling software typically has tools for estimating the available hydrant flow from a single fire hydrant for each hydrant across a network. However, this approach is limited in assessing the availability of larger fire flows, such as the 200 L/s flows required for many buildings in the CBD and industrial areas, as multiple hydrants are required to run simultaneously to meet these larger flows.

4.1 NORMAL MODELLING APPROACH

Assessing larger fire flows drawing from multiple hydrants would typically involve setting up a model run where multiple hydrants are opened, and the individual hydrant flows added to compare with the required flows.

If this approach were used for the whole city, a separate run would be required for each location, as different sets of hydrants would be required, and for different pressures and zoning configurations. The cost to carry out this level of assessment would again be a multi-million dollar exercise, and was not practical within the scope of the Christchurch Rezoning Project, so an alternative approach was required.

4.2 ALTERNATIVE ASSESSMENT APPROACH

The alternative assessment approach was based on recognizing that the higher fire flows required in the Code of Practice require an average of 25 L/s for each hydrant if the maximum number of hydrants is used. The same observation can be applied to FW2 and FW3 if a single hydrant was used for FW2 and two hydrants used for FW3. The required flows and maximum number of hydrants from the Code of Practice is shown in Table 1.

Table 1: Required Flows and Hydrant Numbers (from Standards New Zealand 2008)

Fire water classification	Required water flow within a distance of 135 m	Additional water flow within a distance of 270 m	Maximum number of hydrants to provide flow
FW1	450 L/min (7.5 L/s)	-	1
FW2	750 L/min (12.5 L/s)	750 L/min (12.5 L/s)	2
FW3	1500 L/min (25 L/s)	1500 L/min (25 L/s)	3
FW4	3000 L/min (50 L/s)	3000 L/min (50 L/s)	4
FW5	4500 L/min (75 L/s)	4500 L/min (75 L/s)	6
FW6	6000 L/min (100 L/s)	6000 L/min (100 L/s)	8

The minimum pressure indicated by the Code of Practice is a residual pressure of 100 kPa.

Losses through a tall pattern fire hydrant with a flow of 25 L/s through the hydrant are approximately 80 kPa (Humes Ltd 2013). Allowing for some additional losses through fire service fittings on the hydrant and a length of hose, flows of 25 L/s through a hydrant will result in a residual pressure in the line of approximately 100 kPa. For larger flows if there was a cluster of hydrants in the vicinity, with a flow through each hydrant of 25 L/s, the residual pressure would again be approximately 100 kPa.

If hydrants were tightly clustered, a 200 L/s fire flow from eight nearby hydrants would be possible if the pipe network is capable of delivering 200 L/s to the cluster of hydrants, while maintaining 100 kPa residual pressure, to provide enough head to drive the flow through the hydrants.

The alternative assessment approach is based on assuming hydrants are sufficiently clustered that estimating the amount of flow to each part of the network with a 100 kPa residual pressure represents the available hydrant flow from a suitable number of hydrants in the vicinity. This assessment approach could then be applied using the hydrant testing functionality in the model, with suitable adjustments to the run parameters.

The match between creating a run with multiple hydrants opened, and the alternative approach was tested in a number of locations in the network, generally producing results within 5 % of the multiple hydrant run.

4.2.1 NEAR TO PUMP STATIONS ON LARGE TRUNK MAINS

The Christchurch water supply generally has large mains linking the pump stations, so that large volumes of water are able to be moved across the zones if a pump station is out of action. These volumes are typically larger than the largest fire flow requirements. Typically there are few hydrants on the large mains.

The alternative assessment approach in these areas assumes there are sufficient hydrants so that only 25 L/s is required from each hydrant. On large trunk mains, close to pump stations or reservoirs, this assumption is not appropriate and the alternative assessment approach can significantly overestimate the available fire flow. However, there are generally sufficient hydrants to exceed 200 L/s of available flow, so compliance with the required fire flow is correctly identified in these areas.

4.2.2 NETWORK OF MOSTLY LARGE MAINS

The Christchurch water supply generally has a network of DN200 pipes through commercial and industrial areas, such as the CBD, with some smaller pipes linking the larger mains. In commercial and industrial areas, there are a range of required fire flows, with some larger flows of 150 L/s or 200 L/s likely to be present.

Commercial and industrial areas are generally supplied with a grid network of pipes, with a large number of routes available for water to get to a possible fire site. Hydrants are typically spaced at 90 m and there may be hydrants on two or more sides of the possible fire sites.

In these areas the alternative assessment approach provides a good match with more detailed assessments in industrial and commercial areas, and it is generally slightly conservative when hydrants are available on multiple sides of a building.

4.2.3 SMALLER NETWORK WITH MEDIUM SIZED MAINS

The Christchurch water supply generally has a network of DN150 and DN100 pipes through suburban areas. Most properties in these areas are single family homes, with a few higher fire hazards such as schools and shops. Most properties will require fire flows of 25 L/s, with some 50 L/s or 100 L/s flows.

Suburban areas are generally supplied with a grid network of pipes, with a large number of routes available for water to get to a possible fire site. Hydrants are typically spaced at 90 m, but due to the smaller building sizes, most buildings have hydrants on one side only.

The alternative assessment approach provides a good match with more detailed assessments in suburban areas. In some instances, where there are aged cast iron pipes, the alternative assessment approach can be conservative, as larger flows could be achieved by distributing the flows to multiple hydrants.

4.2.4 ENDS OF NETWORK

The Christchurch water supply generally avoids single end feeds, except in cul-de-sacs, and at zone boundaries.

In a cul-de-sac, most properties will be single family homes with a required flow of 25 L/s, supplied by a DN100 pipe. The alternative assessment approach is conservative for these situations, with all of the flow taken to the end of the pipe. Particularly where an aged cast iron main is present, the difference between using one hydrant at the end of the pipe and two hydrants can be significant. The difference occurs because the headlosses from a flow of 25 L/s to the end of a cast iron main is much larger than a situation where 15 L/s is extracted from a hydrant closer to a junction with a larger or smoother pipe and 10 L/s flows to the end of the pipe.

Zone boundaries can be similar to cul-de-sacs, or may involve larger pipes and more significant fire hazards. The alternative assessment approach does not take advantage of using hydrants from both sides of the zone boundary, so will generally underestimate the available flow in these cases.

4.2.5 OVERALL ASSESSMENT OF AVAILABLE FLOWS

In most parts of the network, the alternative assessment approach produced flows within 5 % of the flows from carrying out a run in the model with multiple hydrants open. The approach over-estimates the available flow near to pump stations and on trunk mains, and under-estimates the available flows at the ends of the network.

When used carefully, the alternative assessment approach provides a practical way of quickly assessing the available fire flow from a cluster of nearby hydrants for each hydrant in a zone. Some adjustments will be required, particularly for the ends of the network.

The alternative assessment allowed the calculation of available flow with the current zone configuration, with the proposed rezoning, and with the proposed rezoning and pressure management applied.

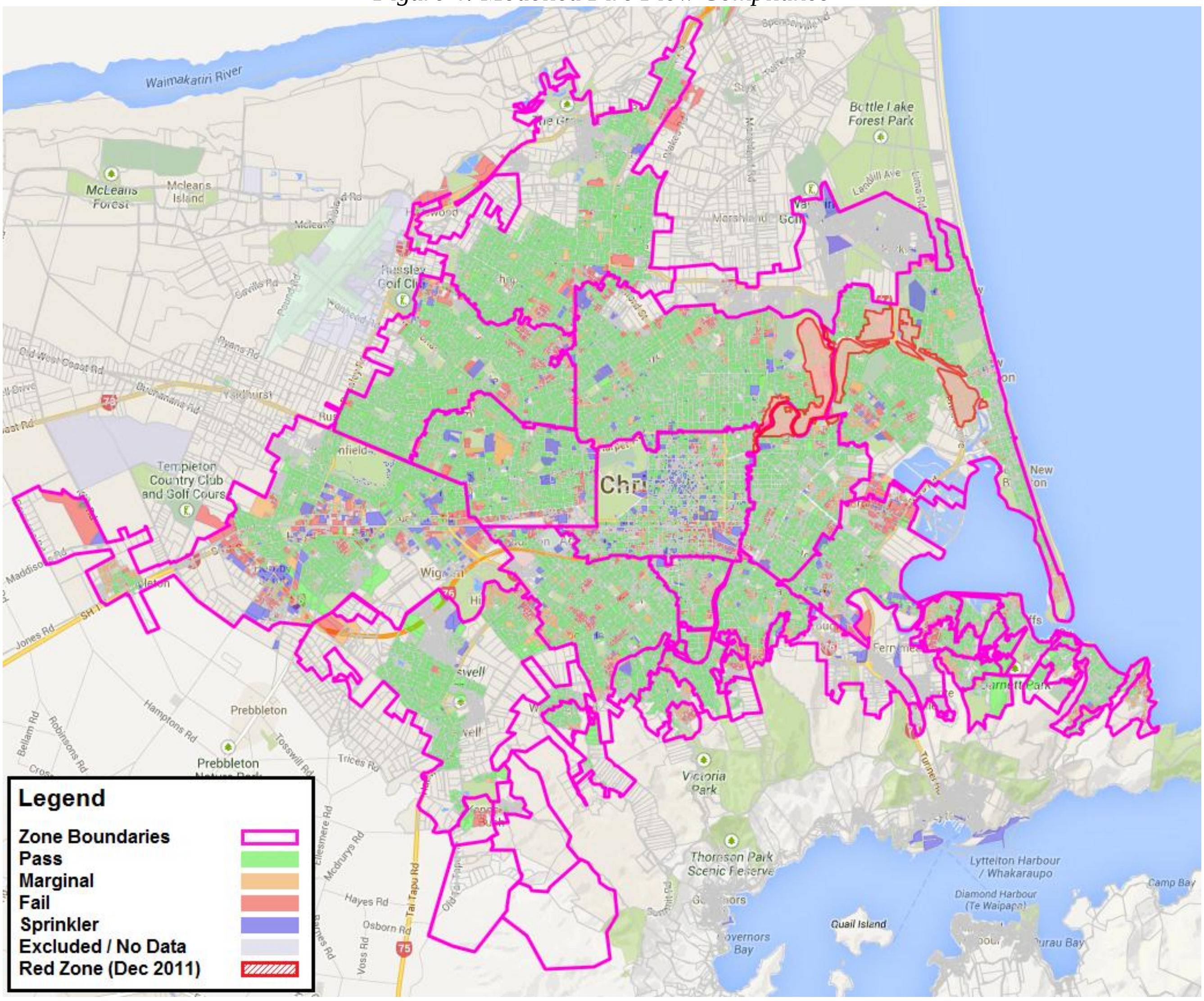
4.3 USE OF GIS

GIS was also used extensively in the assessment of available fire flows. The data for the available fire flow came from a series of model runs, and GIS mapping was used to spatially represent the results to provide direction for further model investigation.

For each building the two nearest hydrants in the network were identified. The average of the estimated available flow of the two hydrants was taken to reduce the effect of the issues at the ends of the network.

The available flow was then able to be compared to the required flow for each land parcel in Christchurch, and each parcel graded as either pass, marginal or fail. Due to the uncertainties in assessing both required and available fire flow, a pass was recognized where available flow was 120 % of the required flow or greater.

Figure 4: Modelled Fire Flow Compliance



GIS was also used to identify the difference in compliance between the current operation, and the proposed rezoning with pressure management applied. This allowed the identification of areas where the rezoning had caused additional fire flow compliance issues. These areas could then be checked in detail, to identify if the issue is a result of problems with the assessment approach, or to design a solution to resolve the issue.

The results of this analysis are preliminary, as a detailed assessment of the actual required fire flows would need to be carried out before any pipe upgrades are installed. The preliminary fire flow compliance situation after rezoning the network and applying pressure management, but before any upgrades is shown in Figure 4. The results of the assessment were used to identify infrastructure works that would improve system performance and may be implemented as part of future asset renewal program.

5 SPRINKLER SYSTEMS

Fire sprinkler systems can also be impacted by the changes proposed in the rezoning.

Sprinkler systems are generally designed based on the available pressure recorded at the site when the system is designed. Due to the high pressures in much of Christchurch, most sprinkler systems have been designed without needing a pump.

The reduction in pressure as a part of pressure management has the potential to affect the operation of sprinkler systems, and require changes to the system to continue to operate effectively. Modifications to a sprinkler system are relatively straightforward during the design stage, but can be difficult to retrofit. Identifying which systems might be affected by the rezoning was important to allow the tradeoff between pressure management advantages and impact on sprinkler systems to be assessed.

5.1 ASSESSMENT APPROACH

The assessment process for sprinkler systems was carried out in two stages.

Protech Design Limited assessed the sprinkler systems that were most likely to be impacted by changes in pressure, and identified the required flows and pressures at the installation gauge for the critical systems. They also assessed the losses between the street and the installation gauge with the design flow, to take into account the service pipe, backflow prevention, strainer and bends.

The models were then used to assess the predicted pressure at the connection to the pipe in the street during the peak day for each of the sprinkler systems assessed by Protech. To deal with the large number of sprinkler systems to be checked, the hydrant testing functions in the model were used to estimate the pressure at the street with the sprinkler flow running. This approach allowed a whole zone to be assessed in a small number of model runs, and avoided potential data handling issues from running each sprinkler system individually.

The results of the model analysis allowed the minimum pressure at the source pump stations to avoid impact on the sprinkler system to be identified.

The approach developed to assess the impact on sprinkler systems could be applied to other areas where pressure management may impact on the operation of sprinkler systems.

5.2 INPUT INTO ZONE PRESSURE DECISIONS

The output of the sprinkler analysis was a list of the critical systems and the required set point for the zone to avoid impacting the performance of the sprinkler system. This gave Christchurch City Council the information to consider the balance between pressure management advantages for the zone, and the number of sprinkler systems that could be affected.

6 CONCLUSIONS

The Christchurch Rezoning Project involved a number of innovative approaches using GIS and hydraulic modeling to assess fire flow requirements, availability and the impact on sprinkler systems, which has allowed an assessment of the impacts of the rezoning on fire flow compliance for Christchurch City Council.

The analysis has given Christchurch City Council the tools to assess the impact on property owners from the proposed changes to the operation of the city as part of the rezoning.

The approaches used could be applied to other water supplies around New Zealand to provide a practical way of assessing fire flow compliance on a town or city-wide basis. Conventional approaches to assessing fire flow compliance would not be practical for most local authorities to carry out.

REFERENCES

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