Pressure management in Waitakere City, New Zealand – a case study

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Abstract In 1996, as part of Waitakere Council’s Water Cycle Strategy, a pressure standardisation programme to permanently lower the average supply pressure citywide was implemented with the aim of reducing water loss and water use. The experience gained during the 1994/95 Auckland water shortage had confirmed that there was considerable scope to reduce pressures in many areas.

Since 1996 water pressures have been reduced in over 60% of the reticulated area of the city, with the average pressure reduced from 710 kPa to 540 kPa. As a result of this programme water loss from the network has been reduced, there has been a reduction in the frequency of mains breaks and it is likely that the life of water pipeline assets has been extended. Furthermore both pressure and demand management initiatives have reduced per capita water use in the city by more than 10%.

A network computer model was used as a design tool to check the network under various pressure regimes and cost benefit analyses were carried out for various design scenarios. Fire sprinkler systems were checked as part of the design process. Minimum service standards were not reduced and in some cases pressures were actually increased. This paper covers the various aspects of the design, the implementation and the results of the pressure standardisation programme.

Keywords Demand management; leakage; modelling; pressure management; pressure reducing valve (PRV)

Introduction
Waitakere City Council’s water business unit (EcoWater Solutions) purchases water from Auckland’s bulk supplier (Watercare Services Ltd) to supply residents and businesses in the city. Bulk water is metered at 28 bulk supply points. All consumption is metered with currently around 59,000 connections made up of residential (79%), industrial/commercial (15%) and agricultural (6%) users. The network comprises 1,267 km of water mains ranging in size from 50 mm to 375 mm. Approximately 60% of the mains are asbestos cement, 30% PVC and the balance are polyethylene, steel, galvanised and cast iron.

In late 1995 Waitakere City Council combined its “Eco city” philosophy with the lessons learnt during the 1994/95 Auckland water shortage to develop a Water Cycle Strategy that promoted sustainable water management solutions at a local level. During the water shortage pressures were reduced as an emergency measure. In 1996, as part of the Water Cycle Strategy, it was decided to implement a programme to permanently lower the average supply pressure citywide to reduce water loss and water use. The water shortage had confirmed that there was considerable scope to reduce pressures in many areas as existing pressures were often well in excess of 300 kPa.

Since 1996 water pressures have been reduced in approximately 60% of the reticulated area of the city with the average pressure reduced from 710 kPa to 540 kPa. Pressures were altered for 35,000 consumers, and in most cases pressures were reduced by between 150 and 500 kPa. Pressure fluctuations were also reduced in many areas as a result of the programme. Water loss from the network and the frequency of mains breaks have significantly reduced as a result of the programme, and it is also likely that the life of water pipeline assets has been extended. With advanced pressure management techniques, future upgrading works may also be deferred as pressures can be increased only during periods of high pressure.
demand. As a greater number of smaller sub zones can now be managed and monitored, leak detection activities are more focussed. Pressure and demand management initiatives have reduced per capita water use in the city by more than 10%.

Design work and implementation was carried out in house by water engineering staff. A network model was used as a design tool to check the network under various pressure regimes, and cost benefit analyses were carried out for the different scenarios. Minimum service standards were not reduced. In some cases zone boundaries were altered and in a few small areas pressures were increased to improve service. The impact of reduced pressures on fire sprinkler systems was considered and affected systems dealt with individually. This paper covers the various aspects of design and implementation of the pressure standardisation programme, and the main results.

Background
The detrimental effect of excessive and unstable pressure in the water supply system on network assets has been recognized in many countries since the early 1980s. The problem can be likened to high and fluctuating blood pressure in the human body. Since 1980 several research activities at a national level have been done, for example, in the UK (UK Water Industry, 1994), and pressure management case studies have been analysed in the UK, Japan, Brazil, and Malaysia (Lambert et al., 1998). Awareness of pressure management and its effects on network assets is now much more acknowledged then previously and a new water supply discipline, pressure management, has developed. In many water authorities, pressure management is widely accepted as having benefits in:

- Demand Management – Less consumption from pressure related uses of water;
- System Deterioration – Extended useful life of infrastructure;
- Water Losses – Reduced leakage and fewer new leaks;
- Maintenance costs – Reduced frequency of main breaks;
- Customer service – Better service due to less water supply interruptions.

The UK Water Research Centre developed a relationship between leakage and system pressure in 1980. Further work carried out since 1980 has confirmed the relationship is dependent on the type of pipeline materials (N1 factor), and Figure 1 below (see Lambert et al., 1998) shows a range of pressure/leakage relationships relating to various N1 values. There is now a good understanding of the way networks respond to pressure changes. Our experience has proven that an N1 value of 1.5, which relates to high pressure systems with predominantly non-metallic pipe materials without significant leakage, applies particularly well to the reticulation in Waitakere City.

![Figure 1 Relationship between system pressure and leakage](https://iwaponline.com/ws/article-pdf/3/1-2/135/477595/135.pdf)
Pilot zone investigations
The first stage of the programme was designed as a trial exercise in a pilot area, as there appeared to be no previous experience in comprehensive pressure management projects in New Zealand. Massey East Zone, with 1,250 connections, was selected for the detailed network investigations. The area was split into a lower and an upper sub-zone. In the lower zone the pressure was reduced by 500 kPa while in the upper zone pressures were reduced 200 kPa. The results from the pilot investigation confirmed expectations. Over the period, the average minimum night flow, as an indicator of losses, was reduced from 1.2 l/s to 0.6 l/s and the total water demand reduced by up to 14%. Only five customers complained about low pressure, all relating to problems with hot water pressure and showers. A plumber at Council’s cost quickly remedied these problems.

Design criteria
Delivery standards
The aim of the programme was to reduce the average supply pressure across the city but maintain the current minimum service standard of 250 kPa pressure and 25 l/min flow measured at the meter. For design purposes 300 kPa residual pressure was required under peak demand and 100 kPa for background use plus fire flows.

It was also necessary for compliant fire sprinkler systems installed before 1996 to remain compliant after the pressure adjustments. This was a responsible approach rather than a legal requirement. A calibrated network model was used to analyse various pressure management options and to check that the supply to critical points was not compromised.

Selection and development of pressure zone areas
The main urban areas of Waitakere City and the northern part of the city i.e. Henderson, Hobsonville, Whenuapai, Lincoln, Swanson, Te Atatu, Kelston, New Lynn, Glen Eden, are relatively low lying and border onto the upper reaches of the Waitemata Harbour. These areas were typically supplied directly via the Watercare trunk water mains with a static pressure of 115 m (HGL) and daily pressure fluctuations between 95 and 115 m (HGL). Thus improvements could be achieved by implementing pressure management, firstly by the permanent rezoning of existing areas where the HGL could be reduced from 115 m to 65 m or 75 m, and secondly, by optimising pressure regimes. As a first step pressure reducing valves with basic fixed outlet pressure characteristics were installed, as the water supply zones were comparatively small. The use of time variable and flow compensating valves was seen as an enhanced option for a future development.

An overview of the system rezoning pressure reduction for four supply zones/sub-zones is given in Table 1.

Hydraulic survey and modelling
A hydraulic survey using solid-state pressure loggers to monitor performance was recognized as an essential step prior to the introduction of pressure reductions. Initially pressure loggers were used to calibrate the network model and to record the pressures occurring prior to implementation of the pressure standardization programme. Prior to making changes to the network, and during the implementation phase of the programme, pressure loggers were used to closely monitor the changes and to verify pressures at the supply points, the furthest points in the zone and the highest points (the critical points), as well as for analysis of PRV performance.

A dynamic hydraulic model (WesNet/InfoWorks WS) was used for analysing how the network would respond to a change in pressure regime, for designing the pressure standardization programme and for operational and planning needs. Separate models were
developed and calibrated for each distribution zone but the intention is to combine these
into a global model as a further enhancement to the modelling. To create the model geometry
for each zone GIS graphical files in CGM form were imported and nodes and pipes
traced directly over background GIS maps. In total the models have 2,502 nodes and 2,909
pipes with a combined length of 668.1 km. Demand is modelled by defining a demand
block (a nodal polygon) as the unit of demand modelling. All elements of the network
including pumps, supply points, reservoirs, and pressure control valves were modelled to
match actual operating conditions.

The models are very stable and the “goodness of fit” between the computed and
measured results is generally in the order of 5%. Models for the entire Waitakere City water
supply system were completed “in house” over a period of 9 months.

Programme implementation

Equipment selection and installation

The results of the hydraulic survey and network modelling were used in selecting and
sizing pressure-reducing valves, water meters etc for each site. The standard installation
consisted of a strainer and PRV installed in one chamber, and the water meter installed in a
separate downstream chamber. The pressure standardisation programme involved bringing
back into service 15 existing PRVs at bulk supply points and the installation of 22 new
PRVs.

Methodology

Once the pressure reducing valves were installed, the pressure reduction exercise was
usually carried out in two steps. Firstly, pressure was reduced half way to the target level
and a few days later the pressure was adjusted to the final level. Over this period, data
loggers recorded inlet and outlet pressures at the PRVs and pressure at critical points in the
zone. In the majority of cases the implementation of the programme was carried out
smoothly without any significant operational difficulties. Furthermore there have been no
significant reticulation problems during subsequent summers when temperatures have
been high and demand at record levels.

The implementation of the entire pressure standardisation programme (35,000 proper-
ties) was carried out with only 1% of affected customers contacting council with a pressure

Table 1  Summary of pressure reduction in water supply for zones 4, 5, 6 and 15

<table>
<thead>
<tr>
<th>No.</th>
<th>Supply zone and sub zone</th>
<th>Initial maximum pressure</th>
<th>Reduced maximum pressure</th>
<th>Pressure reduction</th>
<th>Reduced daily pressure fluctuations</th>
<th>Number of connections</th>
</tr>
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<tbody>
<tr>
<td>4</td>
<td>Lincoln – Swanson</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>7,300</td>
</tr>
<tr>
<td></td>
<td>Lincoln-Swanson Central Sub Zone</td>
<td>115</td>
<td>75</td>
<td>40</td>
<td>20</td>
<td>4,900</td>
</tr>
<tr>
<td></td>
<td>Massey Reservoir Sub Zone</td>
<td>115</td>
<td>100</td>
<td>15</td>
<td>20</td>
<td>1,900</td>
</tr>
<tr>
<td></td>
<td>Simpson Rd Sub Zone</td>
<td>115</td>
<td>100</td>
<td>15</td>
<td>25</td>
<td>500</td>
</tr>
<tr>
<td>5</td>
<td>Te Atatu – Kelston – Glendene</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>7,000</td>
</tr>
<tr>
<td></td>
<td>Te Atatu Peninsula Sub Zone</td>
<td>100</td>
<td>65</td>
<td>35</td>
<td>25</td>
<td>3,100</td>
</tr>
<tr>
<td></td>
<td>Te Atatu South</td>
<td>100</td>
<td>75</td>
<td>25</td>
<td>20</td>
<td>3,000</td>
</tr>
<tr>
<td></td>
<td>Kelston Sub Zone</td>
<td>100</td>
<td>65</td>
<td>35</td>
<td>10</td>
<td>900</td>
</tr>
<tr>
<td>6</td>
<td>Henderson</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>5,800</td>
</tr>
<tr>
<td></td>
<td>Henderson Central Sub Zone</td>
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<td>75</td>
<td>40</td>
<td>20</td>
<td>4,700</td>
</tr>
<tr>
<td></td>
<td>View Rd Sub Zone</td>
<td>115</td>
<td>95</td>
<td>20</td>
<td>20</td>
<td>900</td>
</tr>
<tr>
<td></td>
<td>Pine Ave. Sub Zone</td>
<td>115</td>
<td>90</td>
<td>25</td>
<td>25</td>
<td>200</td>
</tr>
<tr>
<td>15</td>
<td>West Harbour</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>3,000</td>
</tr>
<tr>
<td></td>
<td>West Harbour Upper Sub Zone</td>
<td>115</td>
<td>95</td>
<td>20</td>
<td>15</td>
<td>1,700</td>
</tr>
<tr>
<td></td>
<td>West Harbour Lower Sub Zone</td>
<td>115</td>
<td>65</td>
<td>50</td>
<td>15</td>
<td>1,300</td>
</tr>
</tbody>
</table>
related complaint. Half of these complaints were attributable to customer’s internal plumbing problems such as hot water cylinders and showers. A plumber quickly resolved these problems (often only adjustment) at council’s expense. Some problems took longer to resolve. Problems with plumbing systems and inadequately sized pipes or highly encrusted private galvanized pipes became evident at lower pressures. In some cases the pipe for a new private line was supplied free. Council staff rectified any service connection problems (restricting flow to the meter) at Council’s cost.

Problems in the distribution system were mainly caused by poor PRV performance, e.g., cyclic pressure fluctuations, unstable pressures irrespective of demand, pressure drops during peak demand and valves performing as a direct ratio valve rather than as a pressure-reducing valve. In one or two cases the PRV failed and there was a sudden return to original pressures, which had a very undesirable effect on the network. Other problems encountered were due to faulty valves, one left-hand valve, and ordinary valves being left off instead of being turned on after maintenance.

**Customer relations and fire sprinkler systems**

An important aspect of the programme was dealing with customer relations. The programme was communicated as a “pressure standardisation programme” whereby pressures were being standardised across the city. Notification of the programme and a speedy response to any customer complaints arising from changes in operational pressure was essential. A letter with information about planned activities and a pressure standardisation brochure were delivered to all affected customers. Every customer complaint was followed up promptly and investigated by taking flow tests at the meter, the house tap and a pressure test at the nearest hydrant. Appropriate action was taken to ensure there were no outstanding problems.

To ensure fire sprinkler systems remained compliant after the pressure changes were made a specialist fire engineer was engaged to access the impact of reduced pressures on 70 fire sprinkler systems within the city. Where a problem was envisaged for a particular system the network model was used to confirm final pressures at the location and then the designer of the system was engaged by Council to identify the most cost effective means of overcoming the problem. Some reticulation improvements and upgrading of internal sprinkler installations were carried out and funded by Council to overcome such problems.

**Cost benefit of the programme**

The capital cost for the programme was $850,000 spread over three financial years. This expenditure covered the cost of installing 22 new pressure control sites, laying a few new short pipelines, road crossings, installing new valves, fire system consultants, modifications to existing fire sprinkler systems, plumbing costs and public notification. The key benefits of programme are summarised below.

- Less water consumption per capita largely a result of a reduction in pressure dependent usage, e.g. showers, garden hoses, etc. Per capita water consumption in Waitakere City has reduced by more than 10% since 1992/93 due to the introduction of various demand and pressure management techniques. Pressure management however, is known to be largely responsible for the overall per capita reduction (Montgomery Watson NZ Ltd (1999)). It has been estimated that the quantity of wastewater per capita has also reduced by approximately 4%–5%. One percentage of wastewater volume represents a cost to Waitakere City of approximately $100,000 per year.

- Less frequency of major breaks (i.e. major breaks on a water main or saddle) as shown in Figure 2. In 2000/01 the average number of breaks per month was 48 (or 10 breaks per 1,000 connections). Before 1996 the average number of breaks per month was more than...
65 (or 15 breaks pre 1,000 connections). Fewer breaks means reduced maintenance costs and fewer supply interruptions and consequently improved customer service.

- Fewer water losses. The non-revenue water loss reduced from 14.7% by volume for the 12 months ending June 1996 to 10.5% for the 12 months ending June 2001 (Figure 3). Reducing water losses by one percentage point represents an annual saving to Waitakere City of $65,000, i.e. the 4.2% reduction represents a total saving of $273,000 per annum.
- More efficient leak detection is now possible as 14 new sub zone areas with 22 control points (meters) are now monitored, some using telemetry. This means that the awareness time of unreported leaks is reduced with significant cost savings.
- The life expectancy of water network assets, where pressures have been reduced and pressure fluctuations minimised, has probably been extended by 10 to 20 years.
- Less capital expenditure for future upgrading of the system. Savings in capital upgrading costs to meet population growth is now possible as existing surplus upstream pressure at control points can be used to increase the capacity of the system by simply converting the fixed pressure PRVs to flow modulating PRVs.
- One benefit often overlooked is that private plumbing systems are subjected to a reduced pressure, which in turn reduces faults on private water systems.

A very simple but conservative overall cost benefit for the programme gave a payback period of 3.3 years. This ignores the financial benefits of deferred capital works, reduced wastewater volumes and extended life of assets etc.
Conclusions
For water supply authorities the continuous improvement and development of operational network management is essential to gain the greatest efficiencies in water distribution. Initial results of the pressure standardisation programme in Waitakere City have confirmed that pressure management is a significant operational technique that can be used to great advantage with many benefits. The fact that Waitakere City is supplied by a bulk supplier (Watercare Services Ltd) via 28 bulk supply points supplying 17 discrete water supply zones meant that pressure reduction was perhaps easier to accomplish than for other water utilities; however; it is evident that the benefits of pressure management are too great to be ignored by any water supplier. The benefits of the programme as outlined above are robust and will generate ongoing financial benefits.

Acknowledgements
Waitakere City Council has pursued a progressive approach towards sustainable water management and how this can be achieved at a local level. This paper outlines one of the achievements resulting from this strategic direction. The writers would like to thank Waitakere City Council for being a progressive city and EcoWater management staff for their strong support in the implementation of the pressure standardisation programme.

References