GHOST HUNTING
WATER NETWORK MODELLING TO FIND A PHANTOM BURST

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Abstract

Between 24 and 26 January 2016, there was a sudden drop in both the Mangatawa and Mount Maunganui reservoirs, which feed the Coastal Strip water supply network in Tauranga. The system was already at peak summer demand, and the drop in reservoir levels equated to a further 100 l/s demand on the network. The Coastal Strip network includes Tauranga's heavy industrial area, along with the Port of Tauranga. The idea of this area going dry would give any water network manager nightmares.

As the reservoir levels continued to drop, the water model was used to confirm stop-gap operational measures, which were then put in place to stop the network going dry. The unknown demand slowly disappeared over the next couple of days, and system operation returned to normal. Although the immediate danger appeared to be over, the cause of this large temporary drain on the network remained unknown, and there was a risk it could occur again at any time.

MWH and TCC have worked together for a number of years to develop a good operational water model. Once the dust had settled, TCC asked MWH to undertake an analysis using the hydraulic water network model to look at the event in detail.

This paper outlines how innovative water modelling techniques and collaboration between TCC and MWH were used to find the 100 l/s ghost, and restore the resilience of the Coastal Strip water network.

Key Words: Leakage, Water Modelling, Network Analysis, Flow Meters, Operations

Introduction

Water networks are invisible. We can't see them, so we rely on spies who live in the dark to tell us what is going on. These spies are machines, and where there are machines, there are ghosts. This paper outlines how a combination of data analysis and network modelling were used to catch a particularly nasty ghost in the Tauranga water network.

Background

Tauranga is New Zealand's fifth largest city, with a population of approximately 120,000. The water network consists of around 1,200km of pipes, supplied by two water treatment plants and containing around 20 reservoirs. The city is expected to grow, with the population increasing to around 200,000 by 2063. Tauranga City Council engaged MWH, now part of Stantec, to build a water network model in 2006, with the purpose of developing a master plan for the water network to ensure water supply would be sufficient for the expected growth.

This model has been updated and improved over the years, and the Operations team at TCC have recognised the value of this tool in assisting with day-to-day network operations. TCC Operations and MWH have developed a close working relationship to the point where TCC are able to call MWH with minor but urgent modelling queries such as expected hydrant fire flows, effect of valve closures, or the effects of new developments on the existing network.

The Ghost Appears

On 25 January 2016, TCC Operations noticed that the levels in both the Mangatawa and Mount Maunganui reservoirs were dropping at an alarming rate. These reservoirs normally operate between 75% and 95% full, but in the space of a few hours they had dropped to 50% full.

Both reservoirs are in the Mount Maunganui system. This system is fed mainly from the Joyce high pressure network via the Puwhariki Flow Control Valve, with a small additional low-pressure supply from the CBD, as shown in Figure 1. The setting of the Puwhariki Flow Control Valve varies between 40 and 200 l/s, set automatically depending on the levels of the two reservoirs – if they drop too low, the control valve can supply more water from the high-pressure Joyce system to top the reservoirs up.

Figure 1: Mount Maunganui Network Layout

This setup has been in place and working well for many years, but on 25 January the control valve was delivering its maximum flow of 200 l/s and the reservoirs were not recovering.

Demand analysis on the Mount Maunganui system showed that leakage had jumped from a baseline of around 20 l/s to more like 100 l/s. By anyone's standards, that is a lot of water to suddenly go missing. A leak that size could not just disappear; we would expect it to explode out of the ground somewhere and create a new river. However, there were no reports to council from the public and initial checks along the major pipelines showed nothing.

Meanwhile, the reservoirs kept dropping.

Buying Time

The Mount Maunganui system includes a large industrial area and some of Tauranga's biggest businesses, including the largest consumer of water in the city, Port of Tauranga. Failure to maintain a water supply to these key customers would result in some very serious consequences, so TCC needed a solution and needed it fast.

As shown in Figure 1, there is a closed valve on State Highway 2 which forms a boundary to the Mount Maunganui system. If this were opened, the Mount Maunganui system would be combined with the Papamoa Beach end of the system, including the Poplar Lane Reservoir – this Papamoa system has its own control valve, also supplying water from the Joyce high pressure system to keep the Poplar Lane Reservoir topped up. By combining the systems, TCC thought maybe this could increase total flow into the coastal strip and help keep the two Mount Maunganui reservoirs alive.

Maybe the model could help.

TCC called MWH and asked if they could model the situation to see what opening the SH2 valve would do. The demands in the model were set to match actual daily flow data from 25 January (excluding the missing 100 l/s), reservoir levels were set to reflect actual reservoir levels at the start of 25 January and a 100 l/s mystery demand was modelled in the centre of the Mount Maunganui network. The model was run for 5 days. Sure enough, the two reservoirs drained.

The SH2 valve was then opened in the model, and three hours later, MWH were able to confirm to TCC that opening the SH2 valve would keep the systems alive… for a time.

The model indicated that after around three days, the water level in the Mount Maunganui and Mangatawa Reservoirs would remain sufficient, but the Poplar Lane Reservoir would drain. Combining the systems bought TCC some time, but the clock was still ticking.

TCC opened the SH2 valve, and with both control valves delivering their maximum flow, the system seemed to stabilise.

Magic is Not a Good Thing in Engineering

Over the next couple of days TCC kept an eye on things, and the reservoirs stopped draining. The rate at which water was disappearing seemed to drop, and after around 3 days the missing water faded away altogether into the background noise.

The SH2 valve was closed, and system operation returned to normal. Life carried on. If there was a bullet, it had been dodged. But *something* had happened, and just because it magically vanished did not mean the system was safe.

MWH were again approached to try and make sense of the situation. Through discussions it was decided there were four potential causes for the event, all of which seemed unlikely:

1. A very large leak which somehow slowly repaired itself.
   One possibility raised was that a contractor could have damaged a large water main, then repaired it without informing council. We considered this unlikely, but possible.
2. An extreme change in general demand.
   25 January, when the issue first started, was a Monday at the end of a long weekend and it was the middle of summer. It was conceivable that everyone turned the tap on at once.
3. A genuine one-off demand which council was unaware of.
   As an example, on the long weekend there had been a jet sprint competition in the Baypark Arena. The sprint course had been filled with water over a number of days (and this had been accounted for) but something else may have happened requiring a large volume of water. Council would expect to be informed but for any number of reasons this may not have happened.
4. A metering error.
   Counting against this was the fact that the reservoirs had definitely drained and the system nearly failed – this was not simply an accounting error. If there was a metering error, something else would have to be going wrong at exactly the same time.

At this point, Option 3 (a large one-off genuine demand) was seeming likely. To narrow down the list of suspects, MWH used the model to pinpoint the problem.

Focussing the Lens

A scenario was prepared in the model with flows at Puwhariki and the Harbour Crossing set to match metered data on 25 January. 100 l/s leaks were then modelled at seven different locations between the two reservoirs. The idea was that if there was a large demand near the Mount Maunganui Reservoir, it would draw down the level of that reservoir but the Mangatawa Reservoir would be largely unaffected, and vice versa. By comparing modelled reservoir levels in each scenario to the recorded levels on 25 January, we could identify which scenario was closest to reality, and which location the mystery demand may have been closest to.

This assessment concluded that the mystery demand was close to the centre of the system – Figure 2 shows the location as Point 7. This did seem to rule out the Baypark Arena (which would have drawn down Mangatawa Reservoir more than we had seen), but aerial photography showed Point 7 adjacent to both a golf course and an airport – either one could have a sudden requirement for large amounts of water. In addition, generally higher demand across the system could not yet be ruled out as this would affect reservoir levels in the same way as a demand near the centre of the system.

Figure 2: Location of the Phantom Burst

Tauranga has a good network of district meters, and the Mount Maunganui system is split into seven district metered areas (DMAs). To rule out a general increase in demand, demand was calculated for all DMAs in the Mount Maunganui system for a week before and after 25 January. This showed that regardless of whether they were predominantly residential and commercial, DMAs had essentially the same demand before, during and after the event.

However, two trunk main DMAs also exist – there is metering at each end of these but no customer connections. These should generally show zero demand, but instead we found that on the Matapihi trunk main (conveying water from the Puwhariki Flow Control Valve to the centre of the Mount Maunganui network), there was 80-100 l/s demand starting on 25 January, reducing over the following 3-5 days and fading into background noise after that.

The Game is Afoot

Now we knew we were getting close. With no customer connections on the main it was now clear that this was not a rogue customer, and focus returned to trying to locate a large leak.

We retrieved pressure data at the upstream and downstream ends of the Matapihi trunk main and put it alongside the flow data. This is shown in Figure 3, alongside pressure upstream of the Puwhariki Flow Control Valve. For clarity, Figure 3 is contained in the Appendices. This graph takes some interpreting, but shows the following:

- Before the event, flow through Puwhariki (the green line) sometimes reaches 200 l/s. When this happens, head loss along the Matapihi trunk main (difference between pressures at each end of the main, shown in red and purple) is in the order of 20m. Additionally, head loss in the high pressure Joyce network upstream of the Puwhariki Flow Control Valve sometimes draws pressure at the inlet to the control valve (shown in blue) down to a hydraulic grade line (HGL) of around 90m.
- During the event, flow through Puwhariki is apparently steady at 200 l/s. However, head loss in the Matapihi trunk main is now only 10m, and pressure upstream of the Puwhariki Flow Control Valve is higher, not dropping below 110m HGL.

The model was used again to show that to generate a head loss of 10m, flow in the Matapihi trunk main could not be more than around 100-120 l/s, around 80-100 l/s less than the Puwhariki flow meter was registering.

At this point it occurred to us that the Puwhariki flow meter was different – it does not just report flow, it also controls flow.

The Butler Did It

This is when everything fell into place.

- The flow meter at Puwhariki was faulty and was reporting 200 l/s flow, when the actual flow was around 100-120 l/s.
- As this flow meter believed it was delivering 200 l/s, it was also telling the control valve not to deliver any more flow.
- The control valve was therefore limiting flow to 100-120 l/s, and starving the Mount Maunganui system of water.
- The Mangatawa and Mount Maunganui reservoirs were draining to make up the shortfall.

We contacted TCC and told them of our suspicions. The flow meter supplier was called out to look at the meter, but their calibration test showed good performance as it had in all previous yearly maintenance checks. However, when the flow meter cover was removed, a significant amount of debris was found to have built up within the casing of the flow meter. This may have been affecting electrical connections within the meter as, when this was cleared away, TCC found that even the background noise which had always been accepted as part of the meter data was reduced.

Conclusions - Lessons from the Butler

The network is still invisible. We still rely on the reports from spies we send into the dark, and sometimes those spies tell us lies. We are aware of this, but what can we do? We have to make decisions, so we make decisions based on what the spies tell us and hope that when they give in to the ghosts (as eventually they all will), we can catch them.

More and more these days we are relying on these spies to not only tell us the truth but to make decisions for us as well. This is convenient, but as this story shows, there are risks to be balanced against convenience. Resilience in water networks is rightly recognised as a high priority, but resilience in the flow of information and decision making should also be recognised as a critical aspect of network operation.

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Author Biography

Ben Davies is the New Zealand Discipline Lead for Water Networks Planning at MWH, now part of Stantec. He has 16 years' experience in water network planning and operational network analysis, including water network modelling where required.

Following 8 years working on various demand and leakage analysis projects at Thames Water, Ben returned to New Zealand in 2008. Since then, he has worked at MWH for clients with networks as diverse as the rural networks in Tasman District to the massive Tauranga, Auckland and Wellington urban water networks. Although he has a lot of experience in water modelling, his strength is in seeing where tools such as models can assist in developing a greater understanding of network operations.

Appendix

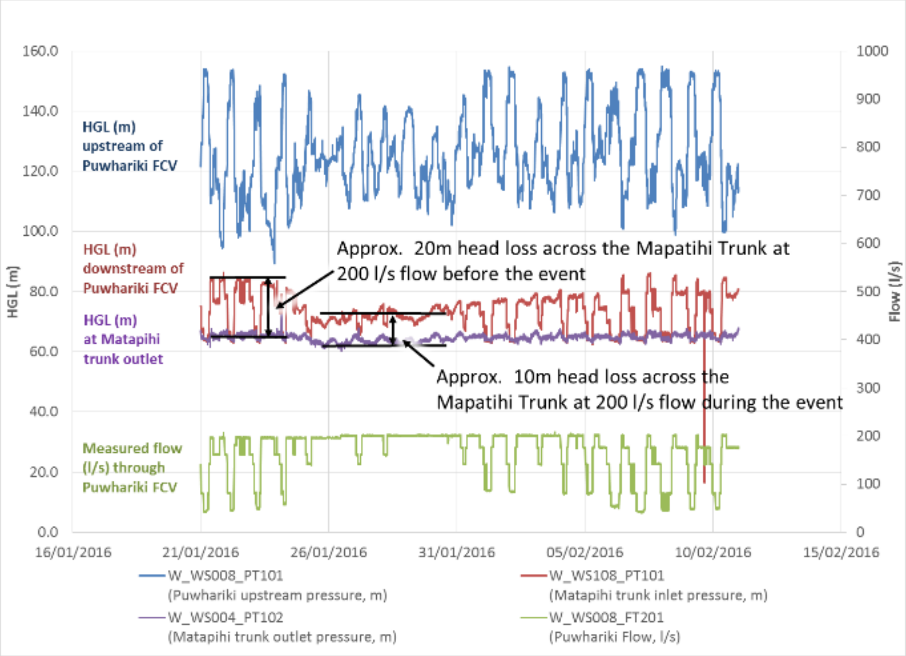

Figure 3: Pressures and Flows in the Matapihi Trunk - The Smoking Gun