THE BATTLE OF WATERLOO

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ABSTRACT

Is, or was, your bore water considered 'secure'? Until December 2016, the bores drawing water sourced from the Waiwhetu aquifer were.

A positive *E.coli* result was returned from water sampled at the Colin Grove bore around two weeks after the Kaikoura earthquake and subsequent heavy rainfall events. This was the first positive *E.coli* result returned from water sampled at the bores along Knights Road in Lower Hutt in over 30 years of operation. The bores met bore water security criteria as set out in the Drinking Water Standards for New Zealand 2005 (Revised 2008). Was this a 'one-off' result? A contaminated sample? Associated with the earthquake? Or potentially another Havelock North?

The Wellington region is supplied with water from three main sources, the Hutt river at Kaitoke, the combined flow from the Wainuiomata and Orongorongo rivers, and the Waiwhetu aquifer. The latter is a particularly important source, often providing up to 70% of the region's drinking water during summer. Eight supply bores drawing from the aquifer were installed along Knights Road in Lower Hutt between 1980 and 1989.

In the months following the initial positive *E.coli* result, a further two positive *E.coli* results were obtained from samples taken from the supply associated with the aquifer. These results required a cross organisational response.

This paper summarises the events leading up to and following the identification of contamination in water sourced from the Waiwhetu aquifer, the water quality challenges faced by Wellington Water during this time, the national context following the Havelock North contamination incident, our approach, and decision making challenges including political and public opposition to chlorination. These were overcome and ultimately work led to permanent chlorination of the Lower Hutt water supply and the fast track installation of UV treatment at the Waterloo Water Treatment Plant.

KEYWORDS

***E.coli*, Bore water security, Havelock North, Chlorination, UV treatment**

PRESENTER PROFILE

Laurence Edwards is Wellington Water's Chief Advisor for Potable Water, based in Petone. His professional experience includes a wide range of three waters infrastructure projects in New Zealand, Australia, and the United Kingdom.

1 INTRODUCTION

The August 2016 Havelock North drinking water contamination incident was estimated to cause around 5,500 of the town's 14,000 residents to become ill with campylobacteriosis, resulting in 45 hospitalisations, and contributing towards four deaths and ongoing health complications for many residents.

Like many ground water supplies throughout New Zealand, the bores supplying water to residents in Havelock North had 'secure' status according to the criteria in the Drinking

Water Standards for New Zealand 2005, Revised 2008 (DWSNZ), and the water drawn from the bores received no microbiological treatment before distribution to consumers.

The subsequent *Report of the Havelock North Drinking Water Inquiry: Stage 2* (Stage 2 report) recommended that the secure classification system in Section 4.5 of the DWSNZ be abolished. However, at the time of writing this paper, a formal announcement abolishing the secure classification has yet to be made.

In the absence of amendment to the DWSNZ, water suppliers across New Zealand are left to consider:

- Could a similar event occur in their supplies?
- What is the level of risk for their supplies?
- Should action be taken to mitigate the risk now, or should they wait for either the DWSNZ to be amended or the government to take action?

The decision making process is complicated by financial implications, political influence, and public opposition to treatment, particularly residual disinfection.

This paper outlines Wellington Water's experience responding to contamination identified in samples drawn from the Waiwhetu aquifer, and the change in our thinking that has occurred with respect to aquifer security. It references the six principles of drinking water safety from the Stage 2 report where considered appropriate.

Perhaps our experience might assist other water suppliers in New Zealand to determine answers to the questions listed above.

2 BACKGROUND

2.1 ABOUT WELLINGTON WATER

Wellington Water is a Council Controlled Organisation (CCO) jointly owned by the Wellington, Hutt, Upper Hutt, and Porirua City Councils and the Greater Wellington Regional Council (GWRC).

In our role as trusted advisor, we have service level agreements in place with all of our client councils. Our agreement with GWRC is to manage its bulk water supply network on their behalf, and the agreement with each of the city councils is to manage the reticulation networks on their behalf. Each council retains ownership of their respective assets.

Guardianship of the Waiwhetu aquifer, which lies beneath Hutt City, comes under the jurisdiction of GWRC.

Providing safe and healthy water is our No.1 service goal.

2.2 GOVERNANCE

Wellington Water is governed by a Board of independent directors, reporting to the Wellington Water Committee. The Board approves the company's strategy, oversees legal compliance, ensures the company has the necessary capability to deliver three waters services and monitors the company's performance, risk and viability.

Each council makes their own level of service and funding decisions with advice from Wellington Water. While GWRC maintains overall responsibility for the treatment plants, improvements made are funded through a bulk water levy that is paid to GWRC by the city councils.

Our Water Committee comprises representatives from each council, and provides governance oversight of the business and of the network infrastructure for the delivery of three waters services. They do this by considering the company's half yearly and annual reports, monitoring performance of the company, appointing directors to the Board, and providing recommendations to shareholders on proposals from the company. The Committee writes an annual Letter of Expectations to the Chair of the Board which is used by the company to develop our Statement of Intent.

Significant technical decisions are made at our Three Waters Decision Making Committee (3WDMC).

2.3 THE WAIWHETU AQUIFER SUPPLY

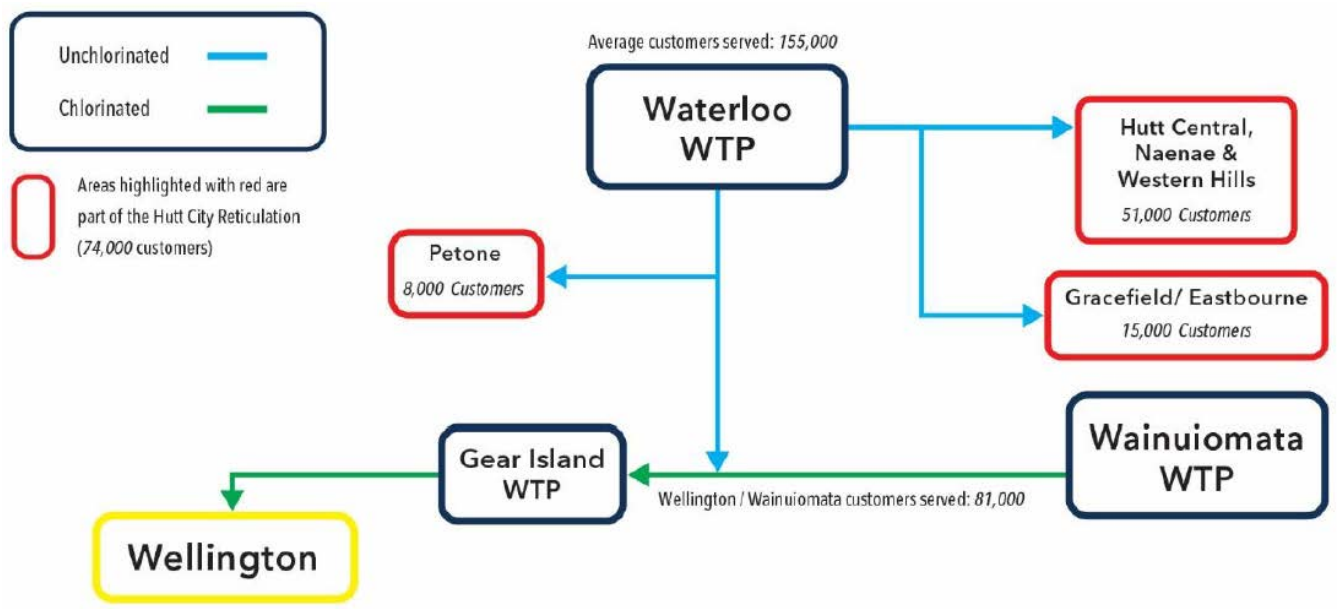
The Waiwhetu aquifer is one of the Wellington region's key sources of fresh water. It can supply up to 70 per cent of the region's drinking water when the availability of surface supplies is reduced, typically during summer. Under normal operating conditions, the water supplied from the aquifer is distributed to approximately 155,000 people in Lower Hutt and Wellington.

Eight supply bores drawing from the aquifer were installed along Knights Road in Lower Hutt between 1980 and 1989, supplying the Waterloo water treatment plant (WTP) via a single collector main. The bores are located in an urban environment, and all bore heads are below ground level. All of the wells are double cased and their construction complies with the requirements of NZS 4411.

Figure 1: Location of Waterloo wellfield bores

The water drawn from the Waiwhetu aquifer that is distributed to much of Hutt City was not normally treated at the Waterloo water treatment plant (WTP) for waterborne pathogens. This is because the aquifer's natural filtration processes and confined environment were relied upon to remove or inactivate them. Water supplied to Wellington from the WTP was treated with chlorine, as indicated schematically below.

Figure 2 – Chlorinated and Unchlorinated Supplies from Waterloo WTP



The bores that supply the Waterloo WTP had secure status under the DWSNZ, and have held similar status under the previous drinking water standards that have applied in New Zealand.

Like many areas of New Zealand, residents of Lower Hutt are very proud of their 'pure' unchlorinated aquifer water. Residents are often seen filling bottles from unchlorinated water bores at Buick Street in Petone and Laings Road at the Dowse in Lower Hutt (see Figure 3).

Figure 3 – The Buick Street unchlorinated water supply bore, Petone

2.4 WATERLOO WATER TREATMENT PLANT

The Waterloo WTP is immediately adjacent to the Waterloo railway station. The plant is split into twin streams, in which the raw water is aerated and dosed with lime to adjust its pH and reduce its aggressiveness to pipework and fittings.

The two streams allow one stream to be taken offline for maintenance while continuing to supply via the other stream, although at reduced capacity.

Figure 4 – Waterloo Water Treatment Plant

The WTP is located in a developed area bounded by the train station, rail tracks, busy roads, and a parking area.

2.5 OTHER REGIONAL TREATMENT PLANTS

The Wellington region is served by three other WTP's, the Te Marua treatment plant in Upper Hutt, the Wainuiomata treatment plant, and the Gear Island WTP. The latter treatment plant is generally used as a standby plant. Storage lakes at the Te Marua WTP provide some buffer against drought events and are typically used between February to May when peak demands are experienced and river conditions are often unsuitable for direct extraction and treatment.

2.6 HAVELOCK NORTH INCIDENT AND INQUIRY STAGE 1

Wellington Water assisted Hastings District Council staff following the Havelock North incident in August 2016.

Following our observations from assisting with that incident, we elected to increase sampling along the Knights Road well field from a single daily sample on the collector main to daily samples at each of the bores in addition to sampling at the collector main.

The proceedings of the inquiry were of considerable interest to us given the potential implications for ground water supplies, the significant population served by the Waiwhetu aquifer, and the criticism of the adequacy and speed of response to earlier indications of concern.

3 CHANGE PRECEDES CONTAMINATION

Stage 2 Report, Principle 4: *Change precedes contamination*
'Contamination is almost always preceded by some kind of change and change must never be ignored. Sudden or extreme changes in water quality, flow or environmental conditions (for example, heavy rainfall, flooding, earthquakes) should arouse particular suspicion that drinking water might become contaminated. Change of any kind (for example, personnel, governance, equipment) should be monitored and responded to with due diligence.'

3.1 EARLY INDICATIONS OF CONCERN

3.1.1 COLIN GROVE E.COLI RESULT

The 14 November 2016 M7.8 Kaikoura earthquake caused significant shaking throughout the Wellington region, resulting in damage to infrastructure including buildings for which repairs are still ongoing. The following day, a significant rainfall event caused flooding in Lower Hutt, including areas around the Knights Road bore field.

Figure 5 – Udy Street Petone, 15 November 2016

Around two weeks later, on 1 December 2016, a routine water sample taken from Colin Grove wellhead returned a positive *E.coli* and total coliform result. This positive *E.coli* result was the first received from water taken from the wellfield since the bores were established in 1980.

Following receipt of the positive result, around 24 hours following collection of the sample, the well was shut down and investigations initiated to assess the possible cause of the water contamination. A further sample of water was taken from the Colin Grove bore prior to its isolation, and that sample was negative for *E.coli*.

After consulting with our advisors and Regional Public Health (RPH), a decision was made not to issue a boil water notice, on the basis that:

- there were no other system water quality results of concern,
- no increased sickness indications were reported by RPH, and
- issue of a boil water notice to such a large population could itself potentially cause significant harm, for example for the elderly or frail handling boiling water.

The Hutt City network and service reservoirs were chlorinated for three consecutive days and samples were collected and tested for *E.coli*, in accordance with DWSNZ requirements. Despite this, Wellington Water elected to keep the Colin Grove bore isolated until investigations to identify the source of contamination were completed.

RPH subsequently wrote to Wellington Water to confirm that the Colin Grove bore had 'provisional secure' status according to the DWSNZ as a result of the positive *E.coli* result.

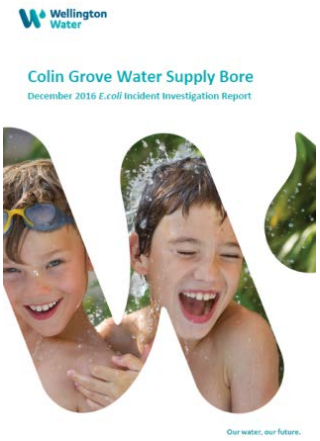
3.1.2 INCIDENT INVESTIGATION

Investigations initiated following the positive result involved various internal teams and consultants and included:

- Assessment of the potential for sample cross contamination and review of the chain of custody of the sample;
- Inspection and reporting on well head condition and contamination risk;
- Leakage testing of well head penetrations to determine possible sources of contaminant ingress;
- Review of the previous bore head security assessment;
- Assessment of the potential for contamination sourced from the wellfield collector main;
- Assessment of the potential for contamination of the aquifer from upstream wells and piles;
- Assessment of potential liquefaction impacting the well as a result of the earthquake;
- Assessment of potential earthquake effects on the Waiwhetu aquifer;
- Assessment of the potential for downward hydraulic gradients at the bores;
- Review of aquifer water quality data to determine if there had been changes in water chemistry since the earthquake;
- Review of Waterloo Water Treatment Plant inlet water quality readings; and
- Review of historical bacterial test results for the Waterloo wellfield.

3.1.3 INVESTIGATION FINDINGS

Figure 6 –Colin Grove E.coli Incident Investigation Report



The investigation work did not definitively identify the source of the positive *E.coli* result in the Colin Grove water sample.

Review of the potential for cross contamination of the sample affecting the positive result indicated nothing untoward. Contamination of the collector main, and contamination of the bore due to liquefaction effects from the earthquake, was determined to be unlikely. Well head penetration leakage testing indicated a minor contamination risk that was resolved, and the bore head security assessment generally indicated nothing considered to be a likely source of contamination.

Contamination of the aquifer due to upstream piles or non-community supply bores was considered to be possible, but unlikely.

A key finding of the work completed was a risk of water being drawn through the aquitard due to downward hydraulic gradients being induced when the water table pressure is higher than the aquifer pressure. This occurs when the bore pumps are running. Downward gradients could draw surface water along the wall of the outer well casing into the aquitard. However as the outer casing terminates within the aquitard, drawdown of contaminants into the aquifer was considered unlikely. In addition, analysis of aquifer water quality test results and online monitoring trends did not indicate any unusual change in the quality of the water in the aquifer that might be expected if drawdown of surface or groundwater into the aquifer had occurred.

Based on the work that was completed, while a downward vertical gradient potentially allows for the flow of surface derived water to the aquifer, it is expected that the confining properties of the aquitard as a whole were unlikely to have changed as a result of the earthquake. Therefore, the risk to the water supply from downwards movement of shallow groundwater through the aquitard to the aquifer in the vicinity of the wellfield is

likely unchanged compared to the pre-earthquake situation, although the risk of discrete pathways adjacent to the well casings remains uncertain.

3.1.4 RESULTING ACTIONS

As a result of the investigations, numerous work streams were initiated including:

- GWRC aquifer investigations.
- Liaison with GWRC to arrange for inspection of the non-community supply bores, as over 50 known bores and pile penetrations were identified within a 1km upstream of Colin Grove.
- Inspection of sewer and stormwater mains in the vicinity of the wellfield to identify and repair any faults.
- Continued monitoring and analysis of water quality trends.
- Continued daily sampling for *E.coli* and total coliforms at all Waterloo wells and from the wellfield collector main.
- Microbiological assessment of total coliform species to determine the potential sources.
- Assessment of options to reconfigure pipework and fittings to further reduce potential for contaminant ingress, including the possibility of moving the well delivery pipework non-return valves to new locations on the well pump riser, below aquifer pressure level.
- Investigating options and costs for implementation of a well scouring/run-to-waste facility to increase system flexibility for well flushing and bore start up procedures.
- Carrying out modelling to better understand the extent of the zone of influence of localised drawdown effects that vary depending on artesian head and the number of pumps running.
- Investigating whether variations in water chemistry at certain wells indicate a significant change in aquifer water quality of any concern.
- Carrying out work to proactively determine what further treatment processes might be required at Waterloo Water Treatment Plant capable of treating contaminated water from the Waiwhetu aquifer, including consideration for detection and management of other forms of contamination such as chemicals.
- Reviewing the existing Water Safety Plan with respect to the findings of the investigation report.
- Obtaining professional advice to better understand what range of factors need to be taken into account to determine appropriate trigger criteria for issue of boil water notices, to ensure we were appropriately prepared to make better informed decisions in the event of any further *E.coli* results.

4 A HIGH STANDARD OF CARE MUST BE EMBRACED

Stage 2 Report, Principle 1: *A high standard of care must be embraced*
'Unsafe drinking water can cause illness, injury or death on a large-scale. All those involved in supplying drinking water (from operators to politically elected representatives) must therefore embrace a high standard of care akin to that applied in the fields of medicine and aviation where the consequences of a failure are similarly detrimental to public health and safety. Vigilance, diligence and competence are minimum requirements and complacency has no place.'

4.1 FURTHER INDICATIONS OF CONCERN

4.1.1 NAENAE RESERVOIR INLET MAIN E.COLI RESULT

A routine water quality sample taken from the inlet of the Naenae reservoir on Friday 3 February 2017 returned positive for *E.coli*. This result was significant as it was taken from the bulk supply main that is immediately downstream of the Waterloo WTP.

We responded by chlorinating the Hutt City Council (HCC) network and sampling in accordance with DWSNZ requirements until three consecutive days of clear *E.coli* test results were received.

RPH, the Wellington Water Board, our client Councils, and the general public were informed of the *E.coli* result and the need for chlorination to protect public health. The public were regularly updated when new information became available, including further water quality test results and the ceasing of chlorination after DWSNZ requirements were met. There were no reports of sickness linked to the positive *E. coli* result. After checking with our advisors and consulting RPH, it was agreed that issuing a boil water notice was not required.

We investigated to determine the likely source of contamination, focusing on the more likely sources including the source water (Waiwhetu aquifer), bore heads, Waterloo WTP, Naenae reservoir, and possible contamination of the sample. As was the case for the Colin Grove investigations, no conclusive evidence was found pointing to any of those potential sources of contamination.

This was particularly challenging as no specific issues were identified to mitigate the risk, and as a result the risk of contamination remained the same as it was prior to the *E. coli* incident occurring.

4.1.2 MAHOE STREET BORE E.COLI RESULT

We received a further positive *E.coli* result from a sample taken from the Mahoe Street bore on 11 April 2017, the third positive result from assets associated with the Waiwhetu aquifer within a 5 month period. The bore was immediately shutdown and retesting at key locations was completed before initiating chlorination of the reticulation network and at the Waterloo WTP. Chlorination continued indefinitely pending completion of investigations and discussion with relevant stakeholders regarding the level of risk from the aquifer source.

The retesting at the remaining operational bores, Waterloo WTP, within the reticulated network and at service reservoirs all returned negative results for *E.coli*. Again initiated investigations did not identify a probable cause of the contamination.

It was agreed with RPH that the issue of a boil water notice was not justified and that public health risk should be adequately managed by chlorine disinfection and confirmation of timely adequate free available chlorine pending assessment of what further work was required. The Mahoe Street bore would however be reclassified as provisionally secure, similar to the Colin Grove bore. The bore remained offline.

We faced a few challenges early on with chlorinating the Hutt City network for extended periods, as the Waterloo WTP dosing system was only ever designed as an emergency standby system. However, these challenges didn't stop us from being able to ensure adequate disinfection levels were met. The system used Calcium Hypochlorite granules that were mixed as a batch then dosed. The system was not a long term solution due to the insoluble material building up in the tanks and clogging of sample lines. The dosing system was converted to Sodium Hypochlorite for ease of operation and increased resilience.

We continued to dose chlorine at service reservoirs until the residual in the Hutt City network stabilised. Daily residual monitoring at sample points continued. A GIS map of

the chlorine residual results in distribution zones was created as an operational tool and also to inform RPH of our work. Disinfection by-products were considered as part of our response, however due to the wellfield supply having very low levels of dissolved organics the risk of disinfection by-products occurring was low.

4.1.3 PUBLIC BORE TOTAL COLIFORM RESULTS

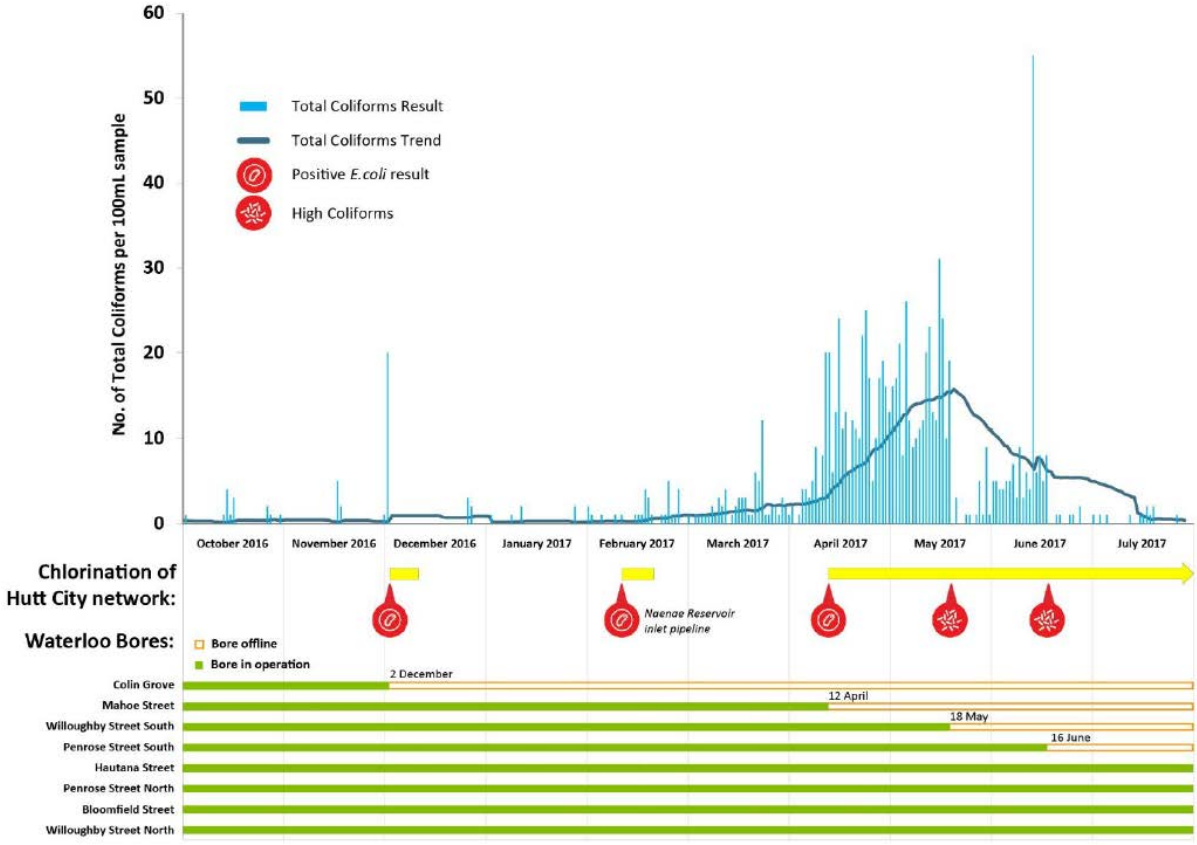
Positive total coliform test results were received for the public raw water supply wells at Buick Street and the Dowse, which received no treatment. As there was a risk that the water in the Waiwhetu aquifer was contaminated, both well supplies were shut down as a precaution following discussion and agreement with HCC.

Figures 7 –Buick Street Raw Water Supply Bore and Closure Notice

4.1.4 INCREASING WELLFIELD TOTAL COLIFORM RESULTS

At around the same time, we observed an increase in the frequency and number of positive total coliform results at various bores in the Knights Road wellfield, as indicated in Figure 8.

Figure 8 – Wellfield E.coli and total coliform results– October 2016 to July 2017



This observed increase in total coliforms led to the decision to shut down the Willoughby Street South bore on 18 May, and subsequently the Penrose Street South bore on 16 June 2017. We also initiated sampling for Protozoa, which returned negative results.

At this point capacity to supply the Waterloo WTP was severely restricted. Fortunately this period coincided with winter demand conditions and high flow available from the other surface sources to meet regional demand, though there was a pressing need to be able to return to full treatment plant capacity prior to the peak summer demand period.

4.2 MINIMISING RISK EXPOSURE

In order to minimise public health risk and exposure of consumers, we limited use of the Waterloo bore field as far as practical. This involved increasing the take from the bores at the Gear Island WTP, as it had no water quality results of concern, and considering alternative means of supplying Lower Hutt from other treatment plants if required.

The realisation that there were surface influences on the bore water, as evidenced by the increasing total coliform results, indicated a need to provide additional treatment barriers to ensure we could provide safe and healthy water.

Our focus quickly turned to fast track installation of a treatment solution for Protozoa protection at the Waterloo Treatment Plant. Three options were considered, Ultraviolet (UV), Ozone and Chlorine Dioxide. Filtration was not considered due to the lack of available space for installation. Ozone and Chlorine Dioxide were discounted as options due to feasibility, time to supply and/or additional technical complications. UV treatment was the only remaining option for rapid procurement and installation.

We contacted various suppliers to determine lead times and availability of suitable UV units, and were offered assistance from other water suppliers that were greatly appreciated.

Fast-track design, procurement and installation of two UV units was initiated through our consultancy panel, with the requirement to complete installation of the first UV unit in the shortest possible timeframe. The need for a run-to-waste facility to avoid potential non-compliance due to possible exceedance of DWSNZ UV turbidity limits was considered. To avoid significant delay to commissioning of the first unit we identified an opportunity to use one stream of the treatment plant for this purpose.

Various options for the permanent run-to-waste pipeline were assessed concurrently with this work, and a preferred option running to the Hutt river was endorsed by the 3WDMC.

Extensive public communications on the need and urgency of the pipeline were initiated. The project was renamed as a first-flush diversion pipeline to avoid negative connotations associated with a 'waste' pipeline discharging to the Hutt river, as although at times exceeding DWSNZ turbidity limits, the water is still of very high quality.

5 SUPPLIERS MUST OWN THE SAFETY OF DRINKING WATER

Stage 2 Report, Principle 5: *Suppliers must own the safety of drinking water*
'Drinking water suppliers must maintain a personal sense of responsibility and dedication to providing consumers with safe water. Knowledgeable, experienced, committed and responsive personnel provide the best assurance of safe drinking water. The personnel, and drinking water supply system, must be able to respond quickly and effectively to adverse monitoring signals. This requires commitment from the highest level of the organisation and accountability by all those with responsibility for drinking water.'

5.1 THIRD PARTY INSPECTION OF WELLFIELD ASSETS

To ensure the highest level of confidence in the integrity of the wellfield assets and discount them as a potential source of the contamination, we engaged a drilling contractor to undertake an independent inspection of the wellfield assets and provide an inspection report.

This work found that the bores were generally well maintained and were in good operational condition, and although their report included some minor recommendations for improvement, these were not considered to be material to the causes of the water contamination.

5.2 STAKEHOLDER ENGAGEMENT

5.2.1 TECHNICAL

The Medical Officer of Health, the Drinking Water Assessor, and water supply treatment experts were invited to attend our 3WDMC for a technical discussion relating to the aquifer contamination.

The purpose of this meeting was to discuss technical aspects relating to the management of the aquifer contamination risk and to agree on the approach for delivering the recommended course of action to other stakeholders and the public. The following key points were agreed:

- Protection of public health is the number one priority.
- Take all practicable steps to reduce risk relating to aquifer.
- The need to take a multi barrier approach.
- Any sudden change in water quality should arouse suspicion, as a precursor to something going wrong.

- No decision has yet been made on the long term treatment processes required, due to uncertainty regarding the source of the contamination and ongoing investigations.
- A number of water supply investigations were in play which may impact on the approach required, and the number of these investigations continues to grow as we learn more.
- The total coliforms results are a warning, indicating a potential contamination route.
- Separating the technical issues from public perception with respect to chlorination, and keeping the chlorine level in the system to adequately protect public health.
- Reflecting on the Havelock North incident - a comparatively small community with high infection rate - and considering the consequences of the same infection rate being applied to our communities.
- The importance of communicating the known facts at the time being 1) the need to protect public health, 2) security of the source water is in question, and 3) that with no chlorine there is no barrier to microbiological contamination in place.
- The need to consider the five barriers of: source protection; effective treatment; secure distribution; effective monitoring; and effective response to adverse signals.
- If there is any doubt, take a precautionary approach to put reliable and safe barriers in place.
- Consider the situation from the perspective of the worst case scenario.
- Focus decisions on the highest possible protection of public health.
- Regional Public Health has powers to issue compliance orders, and if necessary declare a water supply emergency that invokes further powers.
- Support from the Medical Officer of Health on messaging, in particular that the best possible advice is being provided and should be accepted to protect public health, including the need for chlorination.

5.2.2 POLITICAL

The Medical Officer of Health, the Drinking Water Assessor, the mayor of Hutt City Council, the chair of the Water Committee, both the chairman and Chief Executive of GWRC, other councillors from GWRC and HCC, and communications representatives of both HCC and WCC were invited to a subsequent 3WDMC meeting.

They were briefed on the technical decisions made, including continuation of chlorination to maintain a residual in the network until we determine the risk to public health is acceptable, and closure of the Dowse and Buick Street public bores until suitable treatment is put in place. The approach adopted was fully supported by all present.

Discussions were held about other bores in the Waiwhetu aquifer, with GWRC advising that the consents held are mainly for industrial use, and that there was a need to inform all those that could have been affected by the aquifer.

A communications approach aligned with all parties was agreed, including coordination of timing of public communications to ensure all parties were prepared to respond to queries and were comfortable with the information released. It agreed that operational leadership needed to continue to be provided by Wellington Water alongside HCC, GWRC and RPH, and that the communications needed to be front footed for transparency and maintaining public confidence.

5.3 PUBLIC COMMUNICATIONS

As contaminated drinking water can adversely affect many, we endeavoured to ensure our customers were kept up to date. Regular media releases were sent out and our website updated with the latest messaging. Frequently asked questions were developed and posted on our website, initially focusing around the need for continued chlorination of the supply and closure of the Dowse and Buick Street bores.

During this time we were careful not to promise that there would be a discontinuation of chlorination.

5.4 TELLING THE STORY – AQUIFER INVESTIGATIONS REPORT

A report detailing the full extent of our investigations and the decisions made was prepared and made available on our website.

Figure 9 – Wellfield Water Quality Investigations Report

The report provided a comprehensive overview of all investigations completed, a brief summary of the water supply system, test results, regulatory context, discussion, peer reviews from relevant subject matter experts, and conclusions and recommendations around the decision to continue chlorination and fast track Ultraviolet (UV) installation at the Waterloo WTP, in accordance with international best practice.

6 MAINTAIN MULTIPLE BARRIERS

Stage 2 Report, Principle 3: *Maintain multiple barriers against contamination*
'Any drinking water system must have, and continuously maintain, robust multiple barriers against contamination appropriate to the level of potential contamination. This is because no single barrier is effective against all sources of contamination and any barrier can fail at any time. Barriers with appropriate capabilities are needed at each of the following levels: source protection; effective treatment; secure distribution; effective monitoring; and effective responses to adverse signals. A "source to tap" approach is required.'

6.1 THE DOWSE AND BUICK STREET PUBLIC BORES

A non-chemical treatment solution for both the Dowse and Buick Street bores was fast tracked through the design and procurement process, and filtration and UV disinfection was installed by the end of July 2017. These units were designed to meet both bacterial and protozoa protection requirements.

HCC was particularly keen to implement these as quickly as possible, to provide residents with an alternative source of safe and healthy unchlorinated drinking water.

Figure 10 – Package Treatment (UV and filtration) installed at Buick Street

Safe and healthy water could be provided without the need for chlorine from these package treatment plants as there is no distribution network requiring a disinfection residual in case of post treatment contamination.

6.2 WATERLOO WTP UPGRADE WORKS

6.2.1 PROTOZOA RISK PROTECTION

Providing adequate protection for protozoa risk at the Waterloo WTP then became the focus of our attention. Due to the constrained nature of the site, location of inlet and outlet pipelines, and the need to install and commission at least one UV unit in the shortest possible timeframe to mitigate this risk, a design was developed allowing for containerisation of the first unit, to be located close to the existing inlet pipework.

Figure 11 – Installation of UV1 at Waterloo WTP

Figure 12 – Chris Laidlow, GWRC Chairman, at the Waterloo WTP UV plant

This concept also allowed for a second UV unit to be installed in another container above the first UV unit in a relatively short timeframe.

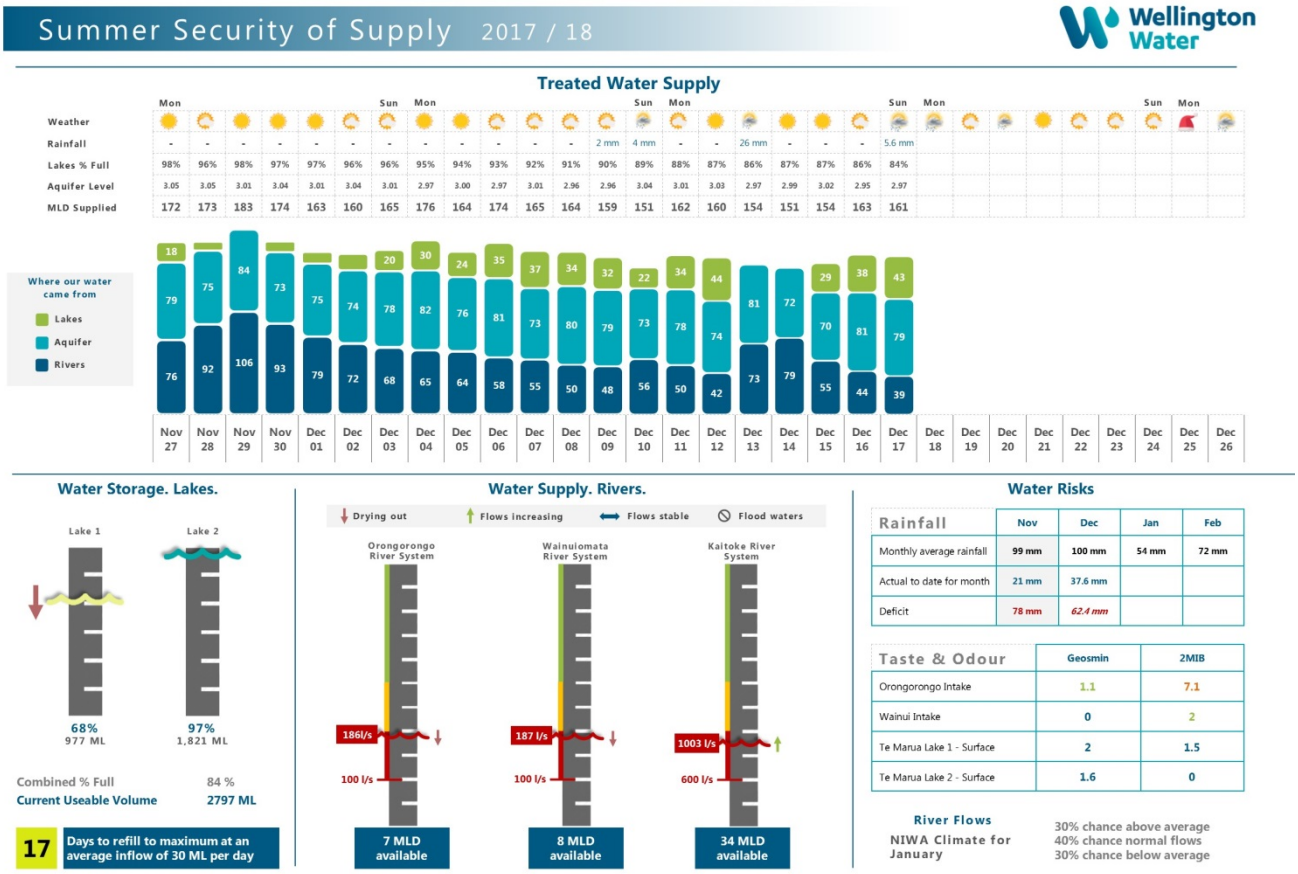
Each unit would provide for up to 60 MLD flow capacity, to ensure adequate supply to meet the region's summer demand.

6.2.2 SUMMER ARRIVED EARLY

Our early planning identified the need to have full capacity restored to the Waterloo WTP prior to the peak summer demand period. The storage lakes at Te Marua are used to provide adequate supply during the peak period, which typically occurs between February and May each year. Our normal operational approach is to preserve the storage lakes to minimise risk of shortages in this period.

Unfortunately, November 2017 was a very dry month, with regional demand increasing dramatically at the same time as availability of river supply plummeting, and as a result we started using the storage lakes at Te Marua much earlier than we normally would have.

Figure 13 – Summer Demand Risk Management Infographic



Regular summer demand risk meetings were held, and infographics prepared to communicate status to our client councils (see Figure 13). A sprinkler ban was issued on 29 November 2017 to relieve pressure on our other treatment plants, which were struggling to meet demand, and to minimise the impact on available storage at Te Marua.

6.2.3 RACE TO THE RIVER

The first flush diversion pipeline needed to be completed prior to peak summer demand to allow the second UV unit to operate within compliance limits, and restore the treatment plant to full capacity.

This involved construction of a new pipeline along Knights Road and through the Hutt Central Business District to an outlet chamber located at the Hutt River, connecting to each of the eight wells along the route, including:

- 1.6km of 450mm OD PE100 SDR 17 pipe;
- Motorized 400mm dia. butterfly valves with actuators;
- Eight poured in situ concrete chambers to house the valves and actuators;
- Various tee and branch sections;
- Multiple pipe specials built to site measurements to divert around existing services;
- Eleven air valves and chambers;
- Two scour systems discharging to existing stormwater reticulation; and
- A discharge structure at the Hutt River.

It was apparent from the first expressions of interest meeting with available contractors

that no individual local contractor could possibly complete the work within the required timeframe, and three local contractors teamed up to meet the challenge.

Work commenced in September, and was completed concurrently over three to four sites at any one time, requiring substantial planning, liaison with HCC, residents and business owners and a significant traffic management presence throughout. Managing health and safety risk was a key focus during the work.

Our communications team worked with the contractors to complete door knocking, letter drops, and face to face consultations with business owners as work was carried out. Weekly advertisements were placed in the Hutt news, informing the public on the progress of the works and what traffic management will be in place for the upcoming week.

Despite the fast track and complex nature of the work, the pipeline was completed and operational by the end of December 2017, and only three complaints were received. Various letters and compliments were also received thanking the team for a well communicated and managed operation, with minimum impact as the works progressed through the city.

7 PROTECTION OF SOURCE WATER

Stage 2 Report, Principle 2: *Protection of source water is of paramount importance*
'Protection of the source of drinking water provides the first, and most significant, barrier against drinking water contamination and illness. It is of paramount importance that risks to sources of drinking water are understood, managed and addressed appropriately. However, as pathogenic microorganisms are found everywhere, complete protection is impossible and further barriers against contamination are vital.'

7.1 AQUIFER INVESTIGATIONS

Protection of the Waiwhetu aquifer is under the stewardship of GWRC, and its primary protection tools are the planning controls it has under the Resource Management Act (RMA).

Our investigations revealed some uncertainty regarding the condition of some the private bores and building piles that penetrate the aquitard and into the aquifer - in particular those built before the introduction of the RMA in 1991.

We commissioned additional aquifer modelling work to better understand the potential extents of negative gradients resulting from drawdown effects of the bores when operating. This work indicated that the negative gradients induced by hydraulic drawdown in the Waiwhetu aquifer were more extensive than anticipated; suggesting that a larger number of private bores and building piles located further afield than initially thought could be potential sources of contamination.

7.2 CONSIDERING FUTURE RISKS

We continue to assist GWRC with an aquifer study seeking to investigate changes to water quality in the aquifer, improve our knowledge of the aquifer, and recommend potential improvements to decision making and resource management practices to protect the source water.

This includes participating in the resource management hearings for the proposed Natural Resources Plan, providing submissions on the importance of protection of the Waiwhetu aquifer as a drinking water resource.

Chemicals and other contaminants of emerging concern are important issues to be considered through this work.

8 APPLY A PREVENTATIVE RISK MANAGEMENT APPROACH

Stage 2 Report, Principle 6: *Apply a preventive risk management approach*
'A preventive risk management approach provides the best protection against waterborne illness. Once contamination is detected, contaminated water may already have been consumed and illness may already have occurred. Accordingly, the focus must always be on preventing contamination. This requires systematic assessment of risks throughout a drinking water supply from source to tap; identification of ways these risks can be managed; and control measures implemented to ensure that management is occurring properly. Adequate monitoring of the performance of each barrier is essential. Each supplier's risk management approach should be recorded in a living WSP which is utilised on a day to day basis.'

8.1 REGIONAL WATER SAFETY PLAN

Subsequent to the Waiwhetu aquifer contamination issue and learnings from the Havelock North Stage 2 report, we have commenced review and revision of the water safety plans for each of our client councils into a single regional Water Safety Plan (WSP). The revised WSP will ensure that a source to tap approach is adopted for management of public health risks, improving on the multiple separate plans for each individual council.

9 CONCLUSIONS

9.1 WHAT DID WE LEARN?

- Knowledge and understanding of your 'secure' aquifer source can change very quickly and without warning. Accordingly we now regard the concept of 'secure' bore water in the DWSNZ as being fundamentally flawed.
- The importance of catchment protection, including with respect to chemicals and contaminants of emerging concern.
- It's much easier and less stressful to take early action in a well-planned approach to minimise the risk, rather than having to act under urgency.
- The condition of our bores and assets are unlikely to have been the source of the *E.coli* contamination.
- The impact of the Kaikoura earthquake and subsequent heavy rainfall events remains uncertain.
- Sampling provides an extremely small snapshot of the water quality in the aquifer compared to the amount extracted on a daily basis (100 ml samples compared to typical daily take of 85 MLD to 110MLD, representing $1x10^{-9}$ % and $9x10^{-10}$ % respectively).
- Clearly, sampling of groundwater when it is deemed to be 'secure' will never have been an adequate method of managing the risk.
- Given the above, we can't rule out the possibility that sporadic contamination of the aquifer has occurred in the past.
- Regardless of the source of the contamination, we couldn't effectively manage public health risk if we continued to supply drinking water from the Waiwhetu aquifer without treating it for waterborne pathogens.
- Not having barriers to contamination in place creates an unacceptable level of risk.

- There is a need for better guidance within New Zealand's drinking water standards around appropriate trigger conditions to justify the issuing of boil water notices, particularly when considering large population bases.
- Independent expert advice aligns with our experience that there is significant public health risk associated with water that is sourced from aquifers and not treated for waterborne pathogens.
- International best practice indicates treating the water supplied by the Waterloo WTP with both chlorine and UV is required to ensure our customers can continue to receive safe and healthy drinking water into the future.

9.2 IT DOESN'T HAVE TO BE A BATTLE

- Providing an alternative means for people to get safe and healthy water without the need for chlorine helps ease the pain (as at the Dowse and Buick Street).
- It's important to focus on the outcome (safe and healthy water), not the means of achieving it.
- There is a need to clearly explain the need to provide a barrier to contamination for the reticulation (residual disinfection), and not just treat the water prior to distribution. The 'secure' status provided for in the DWSNZ is not helpful in this regard.
- Independent inspections and expert peer reviews add weight to the decision making process.
- Front-footing the communications with stakeholders and the public gives the best result in the long run, and builds confidence.
- We need to be careful not to promise our customers something that we cannot guarantee.
- It's important to share the problem, and show what you are working to achieve.
- There are benefits to being a trusted advisor to our client councils, providing advice independently.
- It helps to split technical decision making from political decision making.

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