DARFIELD WATER SUPPLY CONTAMINATION EVENT – LESSONS LEARNED

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ABSTRACT

In August 2012 loss of chlorination of the Darfield backup water supply coincided with failure of the borehole pump for the primary secure groundwater source. At around the same time as this incident, there were 138 suspected cases of campylobacter in the Central Canterbury town. This paper discusses learning from an event that no water supplier would want to happen.

The authors believe that some of the underlying issues that contributed to (but on their own did not cause) the contamination may well be relevant to many suppliers. The background to the incident is described and lessons for wider application in other water supplies are discussed.

KEYWORDS

Water supply contamination, boil water notice, chlorination

1 INTRODUCTION

In August 2012 compliance testing of the Darfield water supply revealed that significant contamination of the reticulation had occurred. At around the same time as this incident, there were 138 suspected cases of campylobacter in the Central Canterbury town. This paper discusses learning from an event that no water supplier would want to happen. Like all events there was a sequence of circumstances and a series of errors that combined to cause a contaminated supply.

However, the purpose of this paper is not to describe the event so that other water suppliers can say "That would never happen to us". It is unlikely that these circumstances will ever be repeated anyway. The authors have written this paper because they believe that some of the underlying issues that contributed to (but on their own did not cause) the contamination may well be relevant to many suppliers.

2 DARFIELD WATER SUPPLY

A schematic of the current water supply system for Darfield is shown below. There are approximately 970 connections (22% are restricted supply connections). The diagram shows that there are two water source options: the SH73 deep well and 3 shallow wells located close to the Waimakariri River. Water from the shallow wells is chlorinated. No other water treatment processes are utilised. Chlorine levels were adjusted to ensure that 0.2mg/l of free available chlorine (FAC) was measurable in the reticulation furthest from the point of chlorine injection when the shallow bores are in use. At the time of the incident, only shallow Well #3 was operational.

The three shallow Waimakariri River wells were the sole source of water supply to Darfield for many years. Gas chlorination is used to disinfect the water. Selwyn District Council (SDC) recognised that this level of treatment was inadequate and did not provide protozoal protection. A major upgrade would be needed to bring the water supply up to an appropriate standard and enable compliance with the *Drinking-Water Standards for New Zealand 2005 (R2008)* (DWSNZ). Alternatives considered included the development of deep groundwater bore sources that would yield water not requiring treatment. An upgrade strategy was adopted, to bring on line two or more deep bore sources and decommission the shallow Waimakariri River wells. By August 2012 one deep bore had been commissioned (SH73 bore). This bore has sufficient capacity to supply peak day demand and is intended to be the primary water source. Until a second deep bore source is commissioned the supply is vulnerable to bore pump failure (or other failure mechanisms) so the shallow Waimakariri River well source is retained as an on-demand alternative water source. Secure groundwater sources with adequate yield are difficult to find in the Darfield area. When they are found, typical bore depths are 200m, nitrate levels are around 0.5 MAV of DWSNZ, and there is entrained air in the water.

The water supply system was configured to allow the wells to operate at any time that reservoir levels, and consequent system pressure, drop to a point that triggered the start-up of a shallow well pump (Well #3). The high yielding deep bore – with an output of 65l/s (consented for 83l/s) has adequate capacity to service Darfield at times of peak summer demand without supplementation from the shallow wells. The gas chlorination system for the shallow bore source has been retained. Of importance to note, however, is that the decision to retain these wells as a backup source did not mean that they were physically isolated from supply.

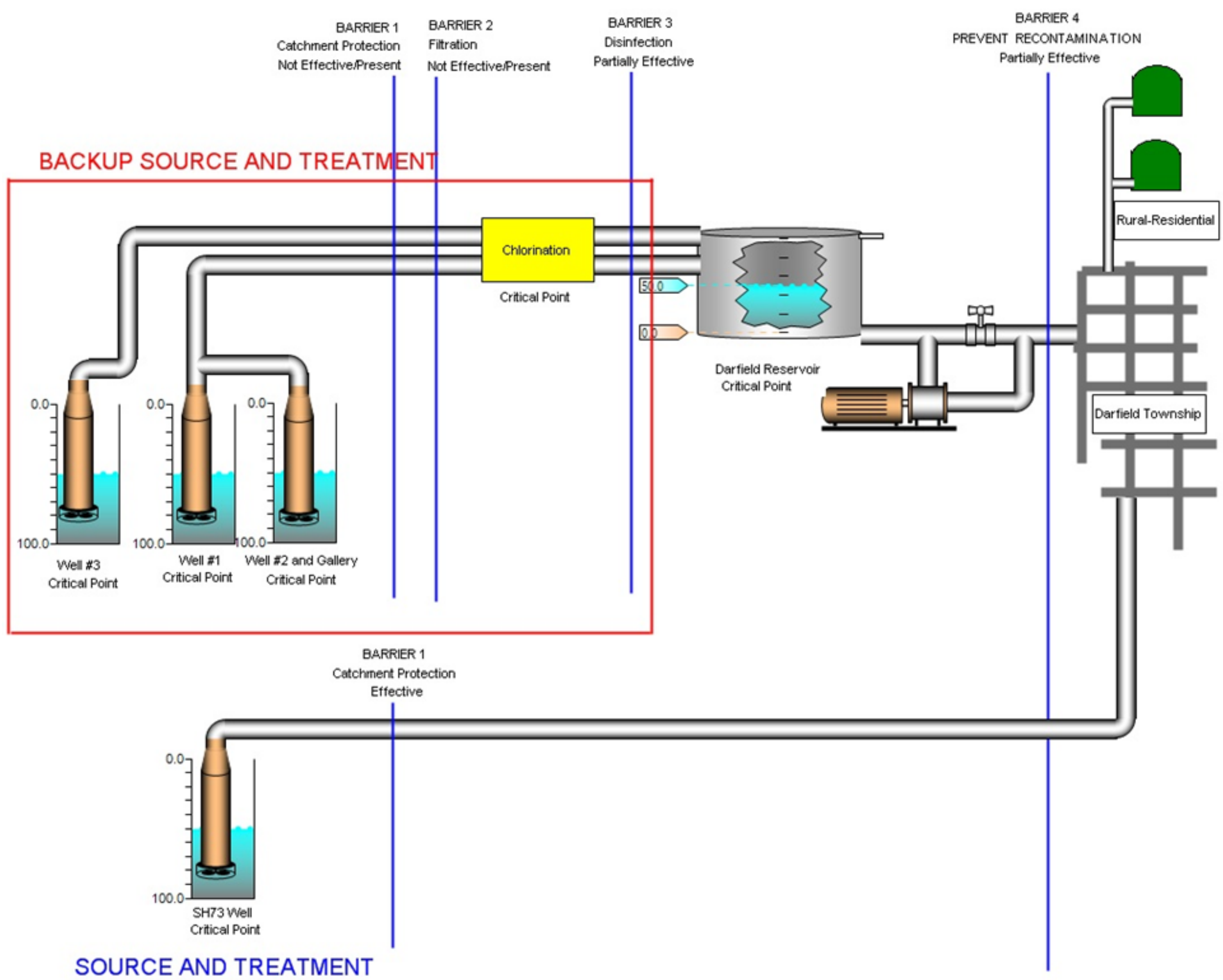

Figure 1: Darfield Water Supply schematic

3 THE EVENT

On 17 August 2012, Hill Laboratories reported a sample taken from Darfield reticulation the previous day as having Escherichia coli (*E.coli*) levels of 70 MPN/100ml and total coliforms of 89 MPN/100ml. Acceptable levels are less than 1 MPN/100ml. The test results indicated the likely presence of faecal contamination of the water supply.

On the same day that the test results were received a decision was taken to notify a Boil Water Notice to the consumers of Darfield.

Subsequent media releases from the Canterbury District Health Board confirmed elevated levels of gastroenteritis in the township that seemed to coincide with the detection of contamination in the water supply.

Internal investigations by the Council confirmed that the high *E.coli* levels detected in the water supply had likely been a consequence of chlorination equipment failure.

Remedial measures with monitoring were undertaken by Council and the boil water notice was lifted on 21 August 2012 after 3 days of clear *E.Coli* tests.

4 SUMMARY OF EVENTS

In November 2011 the Darfield SH73 deep bore was brought online as the main source of water supply to the town. Prior to this the main source of water was from shallow wells located next to the Waimakiriri River (wells #1, 2 and 3). This water from the deep bore fed directly into the Darfield reticulation network. Although the SH73 bore was the main supply of water, the shallow bore supply was used as a supplement at times of high demand. On 16 June 2012 the operating pressure of the deep well pump was lowered slightly to resolve air entrainment issues, this meant that the SH73 deep bore was supplying 55% of the demand and the shallow wellsupplying the other 45%. However, failure of the deep bore pump two days later, meant that Darfield supply was temporarily totally reliant on the chlorinated shallow well supply.

A summary of events up to, and subsequent to, the detection of *E Coli* in the reticulation is provided below. A fuller explanation of the events is outlined in the main report

Date	Event
24 November 2011	SH73 deep bore commissioned.
Unknown	Decision to remove chlorine auto change over unit from shallow well and place it on a surface water source scheme in Springfield.
Unknown	“No chlorine” alarm system planned but not installed at time of event.
Pre 16 June 2012	Water supply to Darfield from SH73 deep bore with shallow riverside well supply water being used as supplement in times of high demand.
16 June 2012	SH73 bore pressure reduced - 45% of demand from shallow well supply.
18 June 2012	Pump failed in SH73 deep bore, shallow bore providing 100% of water to Darfield.

20 June 2012	Pump removed from bore.
21 June 2012	Pump taken to Brown Brothers for investigation
11 July 2012	Chlorine auto change over unit removed from shallow well supply.
24 July 2012	New pumpset ordered for pump.
30 July 2012	New pumpset ready.
9 August 2012	Weekly water sample taken on Darfield reticulation network. *E. coli* level of <1 MPN/100mL.
13/14 August 2012	Significant rainfall in catchment.
14 August 2012	Pump back down SH73 bore (but not operational)
16 August 2012	Weekly water sample taken on Darfield reticulation network.
17 August 2012	*E. coli* level of 70 MPN/100mL reported from Hills Laboratory for Darfield reticulation network.
17 August 2012	Low FAC results throughout network. Chlorine bottle discovered to be empty and replaced at shallow bore supply.
17 August 2012	Discovered that "chlorine empty alarm" was not wired to system at shallow bore supply.
17 August 2012	Boil Water Notice sent out to residents of Darfield.
20 August 2012	New pumpset rewired to system at SH73 deep bore.
21 August 2012	Chlorine bottle empty alarm wired in and tested at shallow bore supply.
21 August 2012	Boil water notice lifted.
22 August 2012	SH73 deep bore supply flushed and brought back online.
22 August 2012	Reservoir site outlet shut. All water to township being supplied by SH73 deep bore.

5 COUNCIL REVIEW

Selwyn District Council management decided that an external review of the events leading up to and after the incident should be undertaken immediately. Of prime concern to Council was the need to ensure practical and feasible mechanisms were put in place to prevent a repeat of such an event. The Author was commissioned to undertake this review.

Any work to establish whether there was a direct connection between the contamination detected and the cases of sickness in the community was outside the scope of the review. However, public health engineering principles demanded that the review be undertaken on the **assumption** that a water supply failure and detection of elevated levels of *E. coli* in the reticulation system presented high risks to public health, and was therefore of extreme concern to the Council.

The review examined the barriers that were in place, whether these barriers were compromised and what improvements should be implemented. The findings of the review are summarised in the following sections.

5.1 TREATMENT AND CONTROL

Ultimate dependence on the deep bore supply will provide full Drinking Water Standards compliance capability once interim groundwater security status is approved. There is every reason to believe that full groundwater security will be confirmed once a full 12 month monitoring programme is completed. Full drinking water compliance includes provision of protozoal and bacteriological protection.

When the chlorinated shallow well supply is used full Drinking Water Standards compliance cannot be achieved. Chlorination of a shallow well or surface water supply does not provide protection from protozoa contamination. Protozoa contamination of surface waters (such as the Waimakariri River) is most commonly derived from livestock- sourced faecal run-off that will have higher loadings after rainfall events.

Chlorination of surface water or shallow well water sources at levels acceptable to the consumer provides bacteriological protection only. Protozoa protection can be provided from secure groundwater sources with no other treatment, or from surface water supplies that use additional treatment processes such as filtration and ultra violet disinfection.

Although chlorination only provides partial microbiological protection for a surface water supply, it is nevertheless a very important treatment barrier. Chlorination of the river supply should be continuous.

When shallow well supply was drawn as an auxiliary supply there was no online mechanism to understand the quality of the water being drawn from the Waimakariri River via the shallow wells. Turbidity and free available chlorine analysers measured water quality leaving the reservoir. The need to calibrate the chlorine analyser had been overlooked, and no one had questioned why the instrument output was “flatlining”. However, potential dilution with the deep well source, settlement of sediment within the reservoir, and reservoir contact time, means the values from these analysers did not represent the raw water quality. Furthermore, they could not be used to directly assess changes to treatment requirements, such as chlorine dose, according to the quality of the water abstracted.

Chlorine dose was adjusted manually. Should manual FAC testing undertaken in the reticulation by Sicon operators indicate low levels (<0.2 mg/l) then the chlorine dose rate was elevated. Water that enters the system from the deep bore will have no chlorine and will always dilute the chlorine added to the shallow well water. An alert to check chlorine levels in the reticulation can be gained by referral to the online turbidity and FAC levels of water that leaves the reservoir and is displayed on SCADA. This alert can be useful if there is confidence that the online analysers are accurately calibrated and can be compared to chlorine levels measured manually in the field with photometers. Prior to the event the contractors photometers had not been recently calibrated.

5.2 CAUSES OF CONTAMINATION

There is little doubt that that the high levels of *E. coli* in water sampled from the reticulation were an outcome of chlorination failure. A more important question is “Why was there a chlorination failure and why was this not detected sooner?”

There were some immediate answers:

- Removal of the chlorine cylinder changeover unit had occurred with no measure to detect loss of chlorine supply. This could have been delayed when it was known that the deep bore supply was not operating

- Use of an uncalibrated chlorine analyser

- Failure to identify chlorine failure through operational checks and inspection prior to the weekly bacteriological compliance testing - noting that fortnightly inspections were carried out by the Contractor – as requested by SDC.

However, the review highlighted a number of otherdeficiencies that each contributed in some way to this failure. Some of these were operational and some were associated with planning and management.

5.3 BOIL WATER NOTICE

Procedures to follow in the event of contamination detected in drinking water supplies were documented by SDC. These procedures determined that for the event of 17 August, a temporary Boil Water Notice should have been issued immediately. It was not clear from this document exactly who is responsible for issuing the notice – the notification to be signed by a “Council engineer”.

A staff member who did not have direct operational management responsibility made the decision to issue the boil water notice. With the test result being received on a Friday afternoon, time was of the essence. Traditional methods were used including press releases, media calls, direct contact with schools, medical centres, but there was also a reliance on using the postal system to deliver letters to each household. Letters were still being received on or about the next Tuesday (the same day as the boil water notice was lifted). As the postal database used the rates register a number of the letters were delivered to absentee owners living outside the district and not to the current householders.

A precautionary approach to water supply contamination is fundamental to public health protection - so the immediate decision to issue such a notice was the correct one.

5.4 ACTIONS FOR COUNCIL

Discussions with staff highlighted concerns over other water supplies where elevated turbidity and positive *E. coli* tests have occurred. Improvements for Darfield were therefore likely to be relevant to other supplies. A number of improvement actions were identified.

Treatment and equipment

i. Priority needed be assigned to gaining bore supply security with an additional deep bore source as backup to the SH73 bore.

ii. If the alternative shallow well source was to be retained as a backup supply it needed to be isolated from the normal supply and manually brought into operation with the knowledge that when operational, protozoa protection was still compromised. There needed to be formalised procedures to follow to avoid abstraction of turbid water for as long as possible and to set, monitor and adjust chlorine dose,appropriate for the raw water quality.

   Abstraction of water from surface water or shallow well sources with elevated turbidity dramatically increases the risk of contamination entry to the supply. (Elevated turbidities will often occur after rainfall events). Apart from isolation from supply to rely on reservoir storage, provision of additional treatment barriers such as filtration and UV disinfection should have high priority for the immediate future. This risk will be even greater if surface run off is from farmland used for dairy production.

iii. Whilst shallow well or surface water sources are retained, operational procedures should be in place to be absolutely sure that chlorination of the supply is continuous. Continuity of chlorination can be ensured through the use of an auto change-over unit. However, If dependence is to be placed on “no chlorine alarms”, they should immediately isolate supply if activated.

iv. When shallow well water is drawn as an auxiliary supply there should be online instrumentation to understand the quality of the water being drawn from the Waimakariri river via the shallow wells.

v. Elimination of the air entrainment is an important objective if there is to be ongoing dependence on turbidity as a true indicator of groundwater quality at the SH73 deep bore.

Connecting asset management and service delivery

vi. There should be collective understanding and input from asset management and service delivery staff, to use risk-based decision making tools for maximising efficiency of expenditure, and to minimise risk exposure. These tools are documented already in asset management plans and public health risk management plans.

vii. Specific responsibility for assigning levels of compliance monitoring, operational monitoring and maintenance activities should be delegated to appropriate staff and contractors to ensure the risk of failure to achieve levels of service is minimised. Once responsibility is assigned, variations in approach between water supplies should be avoided.

viii. Adequate resources and responsibilities should also be assigned to maintain the integrity of data, and the accessibility of this data. Similarly there needs to be resource allocated to ensure all works requests and programmed work as entered on the AMS at asset level is reviewed and followed up where necessary.

ix. The current draft PHRMP should be reviewed and the implementation and review of implementation of PHRMP improvements incorporated into staff work programmes and responsibilities.

x. The Utilities Contract should be reviewed to encourage an environment for the Contractor to assume initiative and responsibility for performance. There needs to be flexibility within the Utilities Contract to allow the Contractor to implement innovation, optimisation and alternative methodologies – without compromising specified performance.

xi. Compliance monitoring should be treated as verification of operational practice – not part of it. Contract requirements that include adequate inspection, maintenance and other field monitoring (eg FAC and turbidity) should be specified for individual supplies after discussion with the current contractor.

xii. The roles and allocation of responsibilities of Contractor staff and SDC staff should be reviewed, formally re-assigned and formally accommodated in SDC staff job descriptions and in Contract provisions.

xiii. In this instance the contractor noted that they operated in a reactive mode only undertaking work if specifically directed by council staff. So although the contract was intended to operate with an output based approach, in effect it was seen as a “dayworks” type operation.

xiv. Operations and maintenance manuals for treatment plants, bores, pumping stations and system control should be prepared in cooperation with the Contractor. The audience for any operations manual is the plant operator. A manual template must therefore be written with that viewpoint.

xv. Testing of alarms displayed through SCADA should form part of a regular maintenance programme that also documents the outcome of the test.

xvi. An alert to check chlorine levels in the reticulation can be gained by referral to the online turbidity and FAC levels of water that leaves the reservoir and is displayed on SCADA. There should be confidence that the online analysers are accurately calibrated and can be compared to chlorine levels measured manually in the field with photometers that are also calibrated. Calibration programmes should be formally documented and records kept on the AMS to confirm the outcome of instrument calibration.

Hygiene

xvii. Hygienic system repair procedures should be written, implemented and audited.

xviii. No reservoir cleaning regime was in place, and the Kimberly Road reservoir should be cleaned and superchlorinated. Superchlorination in this context means achieving a Ct (FAC in mg/l X contact time in minutes) of 7200 mg/l-min.

xix. Reticulation system cleaning and flushing procedures following Boil Water Notices should be documented in cooperation with the Contractor.

Boil Water Notice

xx. Procedures to impose and lift boil water notices for restricted supply consumers should be different to "on-demand" consumers who don't have significant on-site storage. There is the potential for contaminated water to enter rural supply tanks and not be consumed for a number of days, possibly weeks.

xxi. All options available for Boil Water Notification should be considered. Additional options include a direct mail drop, phone trees, text messages, more public signage and the use of cars with loudspeakers - particularly around evening meal time.

xxii. If multiple communication options are used to issue a Boil Water Notice, the same options should be used to notify the clearance once there has been agreement from the Canterbury District Health Board. Written procedures to address the transgression process and Boil water Notices should also document clearance procedures. The clearance procedures should differentiate between restricted rural supplies and unrestricted "direct" supplies. The procedures should allocate specific responsibilities to staff.

6 CONCLUSIONS - LESSONS FOR OTHER WATER SUPPLIES

A programme has been set in place to act on the improvements that were identified in the review process. Many of them are specific to Darfield but others are applicable to supplies within the Selwyn District. The review of this event also posed questions to the authors of a broader nature:

1. Could a similar event occur elsewhere in New Zealand?
2. Could this event have been worse if other forms of contamination had entered the supply?
3. What are the benefits of hindsight for other supplies – in context of the authors' knowledge of the types of supplies and their knowledge of the different operational approaches around New Zealand?

The answers to the first two questions are undoubtedly YES and YES. However, the chances of a similar or worse event elsewhere would be significantly reduced if the lessons learned from hindsight are applied elsewhere. These lessons are summarised below.

Security of Supply and Knowledge of Source Water

Alternative supplies are undoubtedly useful – especially at times of drought or system failure. However the use of an alternative supply should not be automatic and the following questions should be answerable before bringing an alternative supply on line:

- What conditions can arise to cause a deterioration of water quality that cannot be countered by treatment processes?
- What monitoring should be in place to detect water quality deterioration to be able to prevent it entering the system?
- What measures are in place to isolate the supply to prevent contamination entering the system?
- If water treatment of standby supplies cannot meet the DWSNZ, what measures are in place to protect customers from consumption of unacceptable water quality? Where surface water sources are used during high turbidity events, and when treatment processes are inadequate , then a precautionary boil water notice regime may represent good practice, albeit not ideal.

Continuity of Chlorination

In 1998 *Life* magazine cited the filtration of drinking water and the use of chlorine as "probably the most significant public health advance of the millennium."

The importance of chlorination is reinforced in the DWSNZ with chlorination viewed as a primary treatment barrier. There is an implication therefore that if chlorine is used to protect public health it should be operational at all times. The experience from Darfield suggests that multiple measures are appropriate in order to have confidence that chlorine is entering a supply at the appropriate levels. Importantly these measures are simply not about equipment such as automatic changeover units, alarms and on line analysers. Of equal importance are regular inspections of equipment, use of inherent knowledge about the relationships between raw water quality and chlorine demand as well as instrument calibration programmes. And possibly of greater importance is knowing there is active communication between every party involved with operations, monitoring, and system development– whether contractor, contract manager, or council staff.

The value of real time SCADA , alarms , and calibrated monitoring equipment is highlighted during events such as occurred in Darfield

The role of AMPS and PHRMPs

The value of AMPs and PHRMPs should not be under-estimated. In reality they are the principle tools to identify risks, state what is done now to mitigate these risks and to identify future improvements to mitigate risks even further. When PHRMPs are used as inputs into AMPS the improvements identified in PHRMPs can be balanced against pressures on levels of service other than protection of public health. However these documents are only useful if they are removed from the bookshelf and actively used. They should be used to identify capital expenditure priorities as well as operational improvements. However, for the documents to be truly useful, identification of expenditure items within operational and capital expenditure budgets must be then actively implemented. Ownership of these documents should therefore not be confined to the asset manager.

The value of compliance testing

For a community the size of Darfield, weekly *E Coli* testing within the distribution is adequate for compliance purposes. Effectively this implies that for 6 days of a week there would be no sampling taken to detect contamination of the supply if compliance testing was the only mechanism used to detect this contamination.

Compliance testing provides validation not prevention. It is “the ambulance at the bottom of the cliff”.

The provision of potable water to a community, no matter what the size, will occur if there is an adequate fence at the top of this cliff. There can be no better substitute for operational practices that are geared to pre-empting the delivery of poor water quality. These practices include:

- Raw water quality monitoring
- Chlorine demand monitoring
- Spot checking of FAC with portable DPD kits – especially at extremities in system and points of poor circulation

Staff responsibilities and reporting lines

Water suppliers are reliant on the continuous diligence of many people. It is rare for these people to be unaware of their public health responsibilities. The importance of team work and communication is at its greatest when the communities they serve are dependent on potable water. System failures and contaminated water events are more likely to arise when people are unclear of their roles or the roles of others who interact with them. Clarity of responsibilities, definition of expected performance and response, and structured reporting lines are all fundamental requirements when managing a water supply. Unclear definition can lead to duplication of effort as well as omission of effort during the management of a contaminated water event.

Operations and maintenance manuals

In the authors' experience operations and maintenance manuals are often supplied by a designer and rarely used thereafter. The value of these manuals is not for people with system knowledge and experience. Unfortunately, the management of an unwanted contamination event often requires input from people who are not knowledgeable or experienced with the supply. Furthermore, the manuals are often not written in a manner to allow these people to troubleshoot plant problems and to respond systematically to incidents.

Hygiene procedures

Once a water supply is contaminated, the contamination must be removed and proven to be removed. Contaminated water may have entered water pipes, reservoirs and on-property storage tanks. Removal of contamination should include flushing and superchlorination. For reservoirs and tanks, contamination will not be eliminated unless accumulated sediment on walls and floor is removed. Flushing and superchlorination of watermains needs to be planned and systematically implemented to ensure recontamination of cleaned sections does not occur with valving operations in the network during the flushing programme. Flushing volumes should be calculated to ensure adequate turnover of water. Superchlorination should be at adequate levels to disinfect protozoa (Ct=7200mg/l-min) and neutralisation of chlorine with a chemical such as sodium thiosulphate should be planned before discharging chlorinated water to the environment.

All of this work should be complemented with adequate FAC testing and *E Coli testing* in order to demonstrate clearance of contamination.

The process outlined above is not simple – especially for a networked system. The careful documentation of procedures to address these issues is well worth the effort. In the absence of documentation oversight of key steps can easily occur.

Communication of Boil Water Notices

When water is not safe to be drunk, potential consumers need to be told promptly. The messages that are conveyed need to state what not to do, what to do in the interim and for how long any temporary measures should be in place. The experience from the Darfield event was that despite best efforts to communicate there were still customers who were unaware of the event.

The lessons learned around the Boil Water Notice for the Darfield event is probably applicable to other supplies. They address three important areas:

1. Procedures to impose and lift boil water notices for restricted supply consumers should be different to "on-demand" consumers who don't have significant on-site storage.

2. All communication options available for Boil Water Notification should be considered.

3. Written procedures to address the transgression process and Boil water Notices should also document clearance procedures.

During a recent incident in Rolleston (May 2013) a Boil Water Notice was issued under the most extreme conditions (Sunday afternoon on Mother's Day). After the decision to notify its 9000 residents through the use of hand delivered letters, Twitter, Facebook and community email networks the only feedback was that residents were contacted by multiple means.

The maintenance of a close relationship with local public health service representatives, and your council Environmental Health Officers is essential.

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