Case Studies of Outbreaks: Do Not Learn the Hard Way

Ensuring Safe Drinking Water
Learning From Frontline Experience With Contamination

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Contents

Figures vii
Tables xi
Foreword, The Honourable Dennis R. O’Connor, Q.C. xiii
Preface xv
Acknowledgments xvii
Abbreviations xix

1 Introduction 1
   A Message to You .......................................................................................................................... 1
   Our Approach ............................................................................................................................... 2
   How to Benefit From Reading This Book .................................................................................... 4
   Some Perspectives on Accidents and Human Error .................................................................. 5

2 Case Studies of Waterborne Disease Outbreaks 11
   Milwaukee, Wisconsin, USA, 1993 ........................................................................................... 11
   Freuchie, Fife, Scotland, 1995 .................................................................................................... 21
   Nokia, Finland, 2007 .................................................................................................................. 32
   Adliswil, Canton of Zurich, Switzerland, 2008 ....................................................................... 39
   Alamosa, Colorado, USA, 2008 ................................................................................................. 43
   Northampton, England, 2008 ..................................................................................................... 51
   Östersund, Sweden, 2010 .......................................................................................................... 55

3 Detailed Waterborne Disease Outbreak Case Studies 67
   Walkerton, Ontario, Canada, 2000 ............................................................................................ 67
   North Battleford, Saskatchewan, Canada, 2001 ..................................................................... 104

4 Case Studies of Severe Chemical Contamination 123
   Camelford, Cornwall, England, 1988 ....................................................................................... 123
      Case A: Harbor Springs, Michigan, 1977 .............................................................................. 133
      Case B: Vermont School, 1980 ............................................................................................ 136
      Case C: Hooper Bay, Alaska, 1992 ...................................................................................... 137
      Case D: Rural Mississippi, 1993 .......................................................................................... 139
   Burncrooks, Stirlingshire, Scotland, 1997 ................................................................................. 142
## Case Studies of Close Calls 153

- Stratford, Ontario, Canada, 2005 ................................................................. 153
- Brisbane, Queensland, Australia, 2009 ...................................................... 164
- Anytown, North America, 2011 ................................................................. 172
- Anytowns 1&2, Australia, 2011 ................................................................. 183

## Conclusions 197

- Summary of Cases Presented and Other Recent Outbreaks Not Included 197
- Recurring Themes and Lessons ............................................................... 200
- A Preventive Risk Management Mindset ................................................. 207
- Drinking Water Safety Plans (DWSPs) ................................................... 212
- A Proper Value of Drinking Water Operators .......................................... 214
- Ten Commandments for Ensuring Safe Drinking Water ....................... 215

### Appendix A  Summary Timelines of Major Events for Case Studies 217

### Appendix B  Metric Conversions 245

### References Cited 249

### Index 261

### About the Authors 271
Chapter 1

Introduction

A MESSAGE TO YOU

If you are responsible in any way for delivering safe drinking water to a community,* then this book was written for you! Consider the possibility that your actions or inactions in fulfilling your responsibilities could ever cause anyone to experience the kind of real-life horror described for the Walkerton Inquiry by a mother about what happened to her infant son with the following account of their experience with the traumatic events of May 2000 (O’Connor 2002a):

During the May long weekend, the Hammell family was having a garage sale. On Friday, Kody suddenly began to vomit. Mrs. Hammell took him inside to change his diaper and noticed that it was bloody. “I couldn’t even tell what it was,” she said. “I had never seen that before.”

On Saturday morning, Mrs. Hammell woke up to find Kody violently ill. At 10:00 a.m., she phoned the hospital but was told that the hospital was “backed up” and that she should not come in just yet. “Well, when can I come?” she asked. “He’s really sick.” The hospital staff told her to wait until 4:00 p.m. and to get fluids into her son in order to prevent dehydration. “Do whatever you have to do to get it in him,” they said: “get a syringe.”

Mrs. Hammell followed their advice. She got a syringe and “shoved water down his throat.” The water may still have been contaminated, but she did not know that. Finally, she phoned the hospital again around 12:30 p.m. and said, “You’ve got to see him. He’s lifeless. His eyes are rolling in the back of his head. . . . [He has] diarrhea every two minutes. He can’t take it anymore.” . . .

Eventually they were airlifted to London [Ontario]. In the helicopter, Mrs. Hammell asked the doctor whether her son might die. “Yes, he could,” the doctor replied. “We hope to get him there in time.” Fortunately, Kody survived the trip and arrived at the hospital in London, where he was to be

* Including being an Operator, Supervisor, Foreman, Manager, Administrative Officer, Municipal Councilor or Commissioner, Mayor, Utility Board Member or Chair, Regulator, or Public Health Agency Personnel.
put on dialysis the following morning. Again, Mrs. Hammell was told there was a chance Kody wasn’t going to make it. That night, he started to have heart failure and was put on dialysis. While at the hospital, he underwent surgery twice. Finally, Mrs. Hammell said, the doctors told her: “We’re sorry, but we’ve done all we can do. . . . It’s up to prayer and the child’s body to do the rest.” . . .

According to the doctors, Mrs. Hammell said, it was a “pure miracle” that Kody had turned himself around and survived. (O’Connor 2002a; 43–44)

Ultimately in May of 2000 in Walkerton, Ontario, 7 people died including a two-year-old toddler, 27 people (half between ages one and four) developed hemolytic uremic syndrome (HUS)—a serious kidney condition,* and over 2,000 were very ill. The section quoted above is one of three heart-wrenching stories of personal and family suffering caused by this disaster and presented in the Walkerton Inquiry Report (O’Connor 2002a).

As noted in the foreword and preface, Steve was involved with the public Inquiry into the Walkerton outbreak and with investigating what needed to be done to prevent this from happening again. Being exposed to the magnitude of the Walkerton tragedy provided us with the inspiration for our first book on this subject, Safe Drinking Water: Lessons From Recent Outbreaks in Affluent Nations (Hrudey and Hrudey 2004). We presented accounts of more than 70 drinking water disease outbreaks dating back 30 years from 15 developed countries and offered insights into what had gone wrong and what was needed to prevent such problems in future. Yet 60 percent of the cases, some fatal, that we report in this new book have occurred since Walkerton. Clearly, the things that can go wrong to cause drinking water quality problems have continued to occur.

We do not seek perfection; life is not like that. We cannot realistically expect perfection in an activity with the diversity and complexity of providing safe drinking water to communities 24 hours a day, 7 days a week. But we aim, by providing you with an opportunity to experience the authentic problems and pain experienced by others and from an operating point of view as far as possible, to equip you with additional perspective and insight to anticipate and recognize trouble before problem circumstances get out of control. **We believe no reasonable person would want to be responsible for causing the kind of pain and suffering that was experienced by so many people in Walkerton or in many other preventable drinking water outbreaks.**

**OUR APPROACH**

We have prepared the cases that follow primarily for the benefit of frontline personnel, operators, and their direct managers, but we expect these cases will also provide important insights for regulators, public health officials, utility Board members, and/or municipal councilors and commissioners. We have presented each case with a general description of the setting, an account of events as they unfolded provided as far as possible from the perspective of the operators, a description of what actually happened with the benefit of investigation and hindsight, the consequences, a list of questions to ponder

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* “Hemolytic uremic syndrome (HUS) is a condition that results from the abnormal premature destruction of red blood cells. Once this process begins, the damaged red blood cells start to clog the filtering system in the kidneys, which may eventually cause the life-threatening kidney failure associated with hemolytic uremic syndrome. Most cases of hemolytic uremic syndrome develop in children after two to 14 days of diarrhea—often bloody—due to infection with a certain strain of *Escherichia coli* (*E. coli*).” Mayo Clinic Online. http://www.mayoclinic.com/health/hemolytic-uremic-syndrome/DS00876.
about how this case applies to you, and a list of lessons to be learned. These accounts should also be useful for public health professionals and regulators who can benefit from learning about some of the practical challenges that drinking water operators experience.

Fortunately, drinking water outbreaks are extremely rare in developed countries. This means it is unlikely that any of you will be unfortunate enough to experience this kind of failure. However, just as it is extremely unlikely that any of you will win a major lottery prize, inevitably with the large number of lotteries held, lottery winners will be found somewhere. Likewise, given the essential role that drinking water has to human survival—it is required by humans everywhere—future drinking water failures will occur more often than necessary unless approaches to prevention improve. Although such failures may be inevitable over time somewhere, you definitely do not want to be responsible for causing or allowing a drinking water disease outbreak to happen within your system on your watch.

The Research Advisory Panel addressing Part 2 of the Inquiry was seeking to determine how to prevent something like the Walkerton disaster from happening again in Ontario. We had suggested to the panel that we investigate other recent outbreaks in affluent countries (O'Connor 2002b). Working on that suggestion resulted in collection of so much relevant information that, once the Inquiry was completed in 2002, we began writing our 2004 book. We set out to gather as much information from English-language publications as we could acquire to describe what had happened to cause those drinking water outbreaks. While our book has been well received by many water professionals and academics, it was simply not targeted at frontline personnel. With this new book, we hope to achieve a focus that will be more accessible and useful to frontline personnel.

However, the underlying message about what is safe drinking water and how can it be ensured is the same for both these books. Explicit definitions for safe drinking water are surprisingly few, with none to be found in major legislation such as the US Safe Drinking Water Act or the Ontario Safe Drinking Water Act. These absences and lack of clarity have been driven, in our view, by some outdated and truly inaccurate concepts about there being no safe level of exposure to any carcinogen (Hrudey and Krewski 1995). Notably, a number of drinking water contaminants are classified as carcinogens (e.g., arsenic, benzene).

Yet, examination of reality reveals that safety does not demand absolute zero risk, only that the risks should be too small to worry about or to justify any change in personal behavior to avoid. If being safe truly demanded absolute zero risk, then nothing in life could be deemed to be safe. Certainly, providing drinking water continuously that could never pose a risk of any kind under every conceivable circumstance is not something anyone can realistically guarantee. However, a pragmatic concept of safe drinking water ought to be that we can be confident that anyone we care about can drink our local tap water without having to be concerned about a reasonable likelihood of that individual being harmed by doing so, even if very young or very old.

We adopted the adage about a picture being worth a thousand words with our choice of subject for a cover photo (Figure 1-1) for our 2004 book to illustrate what we mean by ensuring safe drinking water. The premise that someone as innocent, trusting, and vulnerable as an infant could suffer serious illness or death from consuming tap water is absolutely unacceptable. Safe drinking water means drinking water that will not cause any such harm.
The most dangerous reaction you can have is to decide that none of these things could ever happen to you or your system. The specific details of these cases may never occur exactly the same way again, but the common contributing factors pose a risk to any drinking water system. In particular, we made the point in our previous book (Hrudey and Hrudey 2004) that microbial pathogens are a widespread (pervasive) risk to drinking water because they arise from fecal material that comes from human wastes, pets, livestock, or wildlife. Where on earth is there a place free of these sources of contamination? Likewise, the chemical contamination cases we review here involve either common water treatment chemicals or other ordinary substances (diesel fuel, detergent) widely used in our technological society. Trouble for drinking water quality and safety does not require exotic chemicals.

**SOME PERSPECTIVES ON ACCIDENTS AND HUMAN ERROR**

The case studies presented in this book document many mistakes and reveal numerous examples of human failing, ranging from simple oversight to intentional cover-up. Accident investigations with all the benefit and perspective of hindsight will commonly attribute many of the causes to human error. As you read these cases, you might be inclined to reach such conclusions about human error in many of them.

Rather than taking the easy path of characterizing every mistake involved in a failure as being a result of human error, we prefer the remarkable insight of Professor Trevor Kletz, a veteran safety engineer who retired from a 40-year career in the chemical industry and who passed away on October 31, 2013, at the age of 91 (Edwards 2013). Professor Kletz explained why simply classifying too much of what goes wrong as being “human error” is itself a serious error (Kletz 2001; emphasis added):

To say that accidents are due to human failing is not so much untrue as unhelpful for three reasons:

1. Every accident is due to human error: someone, usually a manager, has to decide what to do; someone, usually a designer, has to decide how to do it; **someone, usually an operator, has to do it. All of them can make errors but the operator is at the end of the chain and often gets all the blame.**

2. Saying an accident is due to human failing is about as helpful as saying that a fall is due to gravity. It is true, but it does not lead to constructive action. Instead it merely tempts us to tell someone to be more careful. But no one is deliberately careless; telling people to take more care will not prevent an accident happening again. We should look for changes in design or methods of working that can prevent the accident happening again.

3. The phrase human error lumps together different sorts of failure that require different actions to prevent them happening again. (Kletz 2001)

Humans inevitably make mistakes. The focus of reviewing a failure needs to be on how a system allowed a simple mistake or set of mistakes to have disastrous consequences. If we are to reduce failures and minimize consequences, we must have systems (including effective monitoring checks and balances) that can accommodate human error without allowing catastrophic outcomes.
As we review the case studies herein, we need to remember the truism: **Hindsight is usually 20:20 vision.** Someone investigating a failure after the events have unfolded has the benefits of oversight perspective, access to all available evidence, and freedom from making numerous time-sensitive decisions on the basis of incomplete or absent information. Failing to recognize the limitations encountered by the frontline person making the decisions as events unfold will prevent us from understanding what improvements might allow better decision-making in the future. The operator cannot call a time-out—stop the clock, interview everyone about what they knew or saw, and finally take a helicopter ride over the disaster site to get a perspective on what was happening. Yet, accident investigation reports are typically written with those kinds of advantages in perspective, thereby failing to accurately appreciate what the frontline personnel were facing in real time.

Dekker (2006) has provided a detailed guide to doing a better job of investigating failures, mostly using examples drawn from aircraft incidents. Although many obvious differences exist between such incidents and drinking water failures, two key features are similar: such failures are remarkably rare given the countless opportunities for failure and operators (or pilots) are normally highly motivated to prevent failure. Dekker developed a model in which the operator is shown proceeding through unfolding events as if confined within a tunnel, often with branches for which decisions must be made quickly, all the while having to move forward with time. We have adapted these concepts, with helpful inspiration from Ian Douglas (City of Ottawa) to depict what drinking water operators often face (Figure 1-2). The maze illustrated is full of challenges, and progress through this maze is driven by the passage of time.

![Figure 1-2  A day in the life of a drinking water operator](image)
In practical terms, no consequence-free time-outs are available to the operator when things may be going wrong. With experience, the competent operator will learn to navigate through this maze and avoid trouble on a routine basis. However, one day, the layout of the maze may change dramatically or perhaps, even more dangerously, may change only in a subtle but important way. Trouble and failure may eventually follow. This is one downside of experience: it may breed complacency because trouble may not occur for a long time. When trouble does occur, shutting a water system down or calling a boil-water advisory can certainly buy time to sort out this trouble, but such actions inevitably have their own major consequences.

Uncertainty will always exist in real time about whether dramatic actions are needed, but that is the essence of effective risk management: making sensible decisions in the face of inevitable uncertainty (Hrudey and Leiss 2003, Rizak and Hrudey 2006). Because our focus in this book is on facility operations, Figure 1-2 depicts that aspect of providing safe drinking water, but we also note that protecting source water and protecting treated water in distribution from contamination are also key elements of the whole process. Facility operators typically have little control over preventing source water contamination, but they must be aware of that contamination potential to be able to maximize the protection that operating systems can provide for the water they will supply to consumers. Distribution system hazards, as some of our cases highlight, are often difficult to detect because the problems leading to contamination are often out of sight.

Finally, we need to recognize that there is clearly some scope for better training among the improvements required. That is a major motivation for researching and writing this book. We noted in reviewing the more than 70 outbreaks in our previous book (Hrudey and Hrudey 2004):

If the conclusions of every formal investigation of an aircraft disaster were that pilots and other operators in the system were inadequately trained to deal with the challenges of their jobs, there would surely be an outcry from the traveling public to correct this problem. How is it then, that we can find so many failures that indicate inadequate training of operators, designers, managers, regulators and/or health professionals regarding such a fundamentally important service as drinking water and yet have only a muted response towards improving the training and status of drinking water personnel?

Our comment published in 2004 should not be read in 2014 as a universal criticism of events since Walkerton. Many worthwhile advances have taken place, such as the international emergence of support for and implementation of a Drinking Water Safety Plan approach (discussed in chapter 6) and adoption of the underlying culture of knowing your own system better. There have been innovative training initiatives such as that provided by the Walkerton Clean Water Centre in Ontario with its hands-on training programs and broadened curriculum to address public health issues as well as important growth of circuit-rider technical support programs for assisting isolated, remote First Nations communities in Canada. But those we speak with generally agree that much more needs to be done.

The cases that follow in the next four chapters are written from the perspectives of frontline personnel, as events unfolded, to the maximum extent the accessible public information on each case allowed. The amount of detail provided varies from case to
case, depending on the complexity of events and the amount of publicly accessible detail available to us. This was a major constraint for our first case: the massive Milwaukee, Wis., outbreak of March and April 1993. Milwaukee’s outbreak was estimated to have caused more than 400,000 cases of gastrointestinal illness and a possible 50 deaths in the two years following the outbreak among immunocompromised patients residing in a modern city of 1.6 million residents. We follow with six more concise case studies starting with a village in Scotland in 1996, the first well-documented waterborne outbreak of *E. coli* O157:H7; to outbreaks from 2007 until 2011, at least two of which involved fatalities.

Based on extensive reviewer feedback (see the acknowledgments) of an early draft of this book, we have created a separate chapter (chapter 3) for the two very detailed waterborne-outbreak discussions: Walkerton (May 2000) and North Battleford (March–April 2001). The Walkerton discussion is based primarily on O’Connor (2002a), Perkel (2002), other reports in evidence for the Inquiry and actual transcripts of testimony under oath from key players before the Inquiry. Although North Battleford did not have as ultimately serious consequences as Walkerton,* it was also subject to a public inquiry that provided us with a detailed analysis of events and causal factors (Laing 2002) along with transcripts of testimony from key players given under oath. We believe these detailed case reviews can provide frontline personnel with a better individual and personal perspective on those events by furnishing them in a format not previously provided. The level of detail we have used in these cases may be too much for some readers, but others have found it valuable. The organization of these two cases in chapter 3 allows you to skim over some of the detail if not of interest to you and to focus on the causes, potential implications, and overall lessons that may apply to you. We do hope that the human dimensions of the Walkerton tragedy will resonate with readers of chapter 3.

Chapter 4 is a major expansion of our previous coverage with the addition of chemical contamination, a subject we did not address with individual case studies in our 2004 book. We have included such cases here, not because they pose a greater health risk to consumers than the outbreaks we have documented—they do not—but because they are a reality that must always be addressed in providing community water supplies. Noteworthy in these cases is that they do not involve any exotic toxic materials; rather, they were caused by common bulk chemicals used in water treatment and/or widely used substances such as diesel fuel.

Chapter 5 is another new addition to our coverage: close calls. Some commentators use the term *near misses*, but we prefer *close calls* because this avoids the ambiguity that the misses were not *near*: they were misses. We believe that the water industry needs to pursue policies to gather and document experience on close calls to provide meaningful learning materials for operational personnel. The few cases we have been able to include in chapter 5 provide perspectives on the kinds of things that can go wrong for a water utility.

Chapter 6 is a brief wrap-up of the book content that provides a summary of relevant lessons. We believe these perspectives provide an ironclad case for a preventive risk-management approach that can be delivered by developing and using a rigorous Drinking Water Safety Plan: a know-your-own-system approach that has been emerging as international best practice over the past decade. We sincerely hope that readers of this

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* North Battleford had possibly three times as many cases of illness, but no deaths were directly attributed to disease caused by the water contamination.
book will be able to appreciate the merits of that approach and will become advocates among their peers for promoting this outcome.

References cited in each chapter are listed with full details after chapter 6. Finally, in response to reviewer feedback, we have created concise summary timelines for each case study. These are provided in appendix A and may be referred to as needed to keep track of the story for each case.

In closing our introduction, we note that Professor Kletz had a remarkable skill in writing about safety and human factors, which has guided our preparation of this book. In his introduction to his classic guide on hazard identification and analysis for chemical process safety (Kletz 2006), he said in explaining how he followed the advice of Joseph Pulitzer (1847–1911):

“Put it before them briefly so they will read it,
clearly so they will appreciate it,
picturesquely so they will remember it,
and, above all, accurately so they will be guided by its light.”
ALAMOSA, COLORADO, USA, 2008

Alamosa, Colorado, about 400 km southwest of Denver, is a community with a population of about 8,900 located at an elevation of 2,300 m (7,545 ft) in the scenic San Luis Valley with nearby mountain peaks reaching 4,300 m. The City serves as the seat for Alamosa County, is home to a state college, and relies on state tourism, with convenient access to several surrounding attractions.

The Alamosa water system in 2008 consisted of seven deep artesian wells (cased from 150 to 275 m, producing zone 275 to 550 m), two elevated storage towers, one ground-level reservoir (Weber Reservoir), and about 80 km of distribution pipes serving the city and another 1,000 consumers outside of Alamosa itself (Figure 2-14). Unless otherwise specified, the information for this case was derived from the investigation report into this incident (Falco and Williams 2009). At the time of the events described in this 2008 case, the community had no water treatment process and it distributed water without chlorination under a 1974 waiver from the State of Colorado. In Feb. 2008, immediately prior to the case study that follows, only three of these wells were in use.
Outbreak Experience*

The Alamosa water sources were routinely monitored for total coliforms. On Wednesday, Mar. 5, 2008, the routine samples collected by the City for all wells and the Weber Reservoir show total coliforms to be absent (Falco and Williams 2009, Berg 2008). On Thursday, Mar. 6, the first suspected case of salmonellosis was reported to the Alamosa Public Health Nursing Service (APHNS), which started a preliminary investigation. There had been no signals of any water quality problems with the Alamosa system. By Wednesday, Mar. 12, the APHNS had now encountered three cases of salmonellosis and these were reported to the Regional Epidemiologist. By Friday, Mar. 14, the three cases were referred to the Enteric Disease Epidemiologist at the Colorado Department of Public Health and Environment (CDPHE) with up to 19 cases suspected.

* Unlike all but two other cases (Milwaukee and Östersund) in this book which have otherwise been written from the perspective of the operational personnel to the maximum degree allowed by accessible information, this case is written from the perspective of the public health and regulatory officials investigating an outbreak. We could not locate enough information to allow writing this case from the perspective we followed in most other cases, but the comparatively recent timing of this case and the magnitude of the consequences justified including this case in the book.
On Saturday, Mar. 15, the Enteric Disease Epidemiologist at CDPHE initiated an outbreak investigation. This epidemiologist contacted the Safe Drinking Water (SDW) Program at CDPHE on Monday, Mar. 17, to report a disease outbreak in Alamosa and request its assistance in the investigation. CDPHE-SDW established an Acute Team to deal with the emergency, and it directed the City to collect samples from the distribution system for total coliform analysis. As well, the APHNS collected four samples from the Alamosa distribution system for total coliform analysis.

By Tuesday, Mar. 18, 43 cases of gastroenteritis, including 18 laboratory-confirmed cases of salmonellosis, had been reported, making this a very large outbreak—much larger than typical food poisoning cases. Results for the Mar. 17 distribution system samples collected by the City were reported, with two samples noted as turbid and one positive for total coliforms. An advisory was issued to use bottled water (as opposed to a boil water advisory) because the City had already been under scrutiny for frequently exceeding the maximum contaminant level (MCL) for arsenic that occurred naturally in the groundwater source and because the current source of contamination was unknown. Furthermore, during the course of the system flushing, high chlorine levels were expected to be used. A key factor in calling the advisory was that five infants who had no food exposure other than formula prepared with Alamosa tap water were among those reported ill.

The City and the County declared an emergency and a mutual-aid support network of water utilities, the Colorado Water/Wastewater Agency Response Network (CoWARN), was activated to assist the City of Alamosa in dealing with this water crisis.

On Thursday, Mar. 20, five water samples from the Alamosa distribution system were collected by CDPHE-SDW staff for *Salmonella* analyses, along with one additional sample from the adjacent distribution system for East Alamosa, which at that time* was separate from Alamosa. Three potable water distribution centers were opened and teams from CoWARN arrived to assist Alamosa.

By Friday, Mar. 21, 138 cases had been reported, the State Governor declared a state of emergency, and the National Guard was deployed to assist with bottled water distribution. Disinfection and flushing of the Alamosa system were initiated, the Weber Reservoir was drained, and crews began cleaning the sediment collected there. This work continued on Saturday, Mar. 22, finishing with the reservoir being sprayed with a 50-mg/L chlorine solution that was left in place for 24 hours.

On Easter Sunday, Mar. 23, the Weber Reservoir was rinsed and filled with 1 ML of 25 mg/L chlorine solution for a further 24-hour contact time. Crews from CoWARN studied the Craft water tower for cleaning and the distribution system for cross-connections, and they planned the flushing program for the distribution system.

On Monday, Mar. 24, all five water samples taken by CDPHE-SDW staff reported positive for *Salmonella* by polymerase chain reaction (PCR) analysis, a sensitive and specific indicator for the presence of microbial genetic material.† The one sample collected for the separate East Alamosa distribution system was PCR-negative, a finding consistent with the contamination being limited to the City of Alamosa. CoWARN called for additional distribution system operators across Colorado to assist with the disinfection and flushing programs. The Craft tower was drained and then filled with 1.9 ML of 25 mg/L of chlorine that was held in this tank for 24 hours. The chlorine demand was not reported.

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* East Alamosa is now part of the Alamosa system.
† PCR does not allow quantification nor determination of viability of pathogens.
On Tuesday, Mar. 25, the water sample cultures at the State Laboratory showed growth of *Salmonella*. The CDPHE-SDW team began super-chlorinating the Alamosa distribution system, flushing from north to south. Public notifications were done by door-to-door leaflets and with traffic signs across the community. Schools in Alamosa were closed.

On Wednesday, Mar. 26, water from the disinfected Weber Reservoir and the Craft tower was used for distribution system flushing. The Ross tower was drained and flushed before being filled with 0.76 ML of a 25-mg/L chlorine solution and held for 24 hours.

On Thursday, Mar. 27, the case count reached 286, with 73 confirmed and 11 hospitalizations. The *Salmonella* cultures allowed for performance of pulsed-gel-electrophoresis (PGE) molecular (genetic) typing, which demonstrated that the *Salmonella* strains from the water samples matched the strains obtained from victim stool samples, thereby providing compelling evidence that Alamosa tap water was the source of this *Salmonella* outbreak. Distribution system flushing continued.

On Friday, Mar. 28, the case count showed a slowing rate of increase, reaching 293 reported cases, with 78 confirmed and 12 hospitalizations. Ninety percent of the food service establishments had reopened. On Tuesday, Apr. 1, the City of Alamosa issued a press release advising that the bottled water order was still in effect for drinking and cooking, but showering and clothes washing with tap water were now allowed. Disinfection and flushing were completed by Wednesday, Apr. 2, and on Thursday, Apr. 3, the bottled water advisory was reduced to a boil water alert for all consumption uses, but bottled water use was still required for infant formula.

The crisis was lessening by Monday, Apr. 7, over a month after the first case emerged, with demand for bottled water declining. On Tuesday, Apr. 8, the CDC reported unconfirmed possible presence of *Cryptosporidium* and *Giardia* in water samples taken before flushing. The boil water advisory remained in place while samples for the protozoan pathogens were collected and driven to Denver for rush analyses on Wednesday, Apr. 9.

The rush samples came back negative for *Cryptosporidium* and *Giardia* on Thursday, Apr. 10. Finally, on Friday, Apr. 11, the boil water advisory was lifted. Residents were instructed to replace water filters and flush water-using appliances by running them to empty a number of times.

### What Actually Happened

The CDPHE-SDW team conducted an investigation (Falco and Williams 2009) of the Alamosa water system in search of an explanation for the *Salmonella* contamination because the wells supplying the system had been providing water generally free of total coliforms (six positive in 2002, one positive in 2003, all negative on resampling), suggesting either a recent contamination of the wells, or more likely, contamination within the distribution system. If this system had been chlorinated, the impact of contamination could have certainly been reduced. Likewise, careful monitoring of chlorine demand in the distribution system could have detected signs of the contamination much earlier.

Of the three wells supplying the Alamosa system prior to the outbreak, the Weber well, which fed the Weber Reservoir, provided 75 to 80 percent of Alamosa’s water. The remainder came from the Cole Park well (15 to 20 percent) and the 12th Street well (less than 5 percent), both of which fed the distribution system directly, bypassing the Weber Reservoir. Records indicated that the Cole Park well was built in 1936 and the Weber well in 1956. They were lined with solid casing to depths of 150 to 275 m and they had at least some grouting near the surface. While these wells penetrated shallow groundwater
in an unconfined aquifer, they were not designed nor intended to draw any water from these shallow sources. Attention was focused on the Weber well and the Weber Reservoir because only this source could explain the extent of the Alamosa distribution system that was apparently contaminated, based on the distribution of salmonellosis cases. Although the Ross and Craft towers were also evaluated for contamination and vulnerability to contamination, only the Weber Reservoir could have provided a source of contamination that would have reached throughout the Alamosa distribution system. Furthermore, finding total coliforms in the Weber Reservoir, but not in the Weber well, pointed to contamination of that reservoir, rather than contamination downstream in the distribution network. The vulnerability of the two water towers will not be considered further in this discussion.

The Weber well had a number of vulnerabilities including some corrosion and damage to the well casing, two lines penetrating the casing near its top, and a discontinuity in the casing at about 290 m depth. The two lines penetrating the casing were believed to be drain lines connected to a common header that was controlled by a valve and then drained to a vault. This drain line had no flap valve or cover to limit access back to the well. Despite these vulnerabilities, there was no evidence indicating that the Weber well water had been the source of *Salmonella* contamination.

The Weber Reservoir is a 1.2-ML rectangular concrete reservoir, constructed in 1979, below grade surrounded by a berm. The reservoir was inspected in 1997 showing that the roof, exterior wall surface, and foundation were satisfactory, but the exterior corners “were in poor condition” and the exterior walls and foundation had “some cracking, spalling and exposed aggregate” (Figure 2-15; Falco and Williams 2009, reproduced with permission) with sediment an average of 1 in. (2.5 cm) deep on the floor of the reservoir. City records indicated that the last time Weber Reservoir had been drained and cleaned was in 1984, 24 years before the outbreak. The 1997 inspection report recommended that the reservoir should be inspected and cleaned every 3 to 5 years, but there was no evidence of any follow-up action on these recommendations during the subsequent 11 years. The Weber Reservoir received a visual inspection in 2006 that revealed no structural issues so a decision was made to leave the Weber Reservoir in potable service until a new water treatment plant, planned for 2008 and designed to deal with the natural arsenic contamination of the groundwater source, could be brought into service. A potential for the Weber Reservoir to have a backup cross-connection with storm drainage was acknowledged by the City, but the conditions required to cause this backflow apparently had not occurred prior to this incident in 2008.

The distribution system was assessed by a team from CoWARN for potential cross-connection hazards, and three locations considered to be potentially extreme hazards—two mortuaries and a combined meat packing and restaurant facility—were identified. None of these was judged to have been responsible for the *Salmonella* contamination because no sources of *Salmonella* were identified. Additionally, more than 100 other sites had taps identified as potential cross-connections, but these were not judged to pose an extreme risk.

Overall, the most plausible explanation for *Salmonella* contamination was the entry of fecal contamination carried by rain or snowmelt through cracks in the roof and sides of the tank (Figure 2-15). Small animals or birds may also have entered the Weber Reservoir through one or more of the larger holes, but no bird or animal carcasses were located. Bird fecal material was present on the roof of the reservoir. Unfortunately, samples of
the sediment that had been cleaned out of Weber Reservoir were not handled properly, making inconclusive the negative results obtained for *Salmonella* analysis of the sediment samples. Because the well water was naturally warm (>24°C), moist warm air venting through holes in the reservoir would likely have been attractive to wildlife. The potential occurrence of *Salmonella* in wildlife feces (including birds) is well established (Fennell et al. 1974, Refsum et al. 2002, Smith et al. 2002, Renter et al. 2006, Hall and Saito 2008), and wildlife sources have been suspect in causing several waterborne outbreaks including Riverside, Calif., in 1965; Greenville, Fla., in 1983; and Gideon, Mo., in 1993 (Hrudey and Hrudey 2004). If *Cryptosporidium* had been confirmed (samples were negative for *Cryptosporidium*), the theories of contamination might have also included small mammals in addition to birds, because the latter are not known to carry *Cryptosporidium*.

**Consequences**

Salmonellosis can cause gastroenteritis, enteric fever, and, in severe cases, blood poisoning. Symptoms may involve acute inflammation of the small intestine and colon accompanied by sudden onset of headache, abdominal pain, diarrhea (bloody in up to 30 percent of cases), nausea, and possibly vomiting. In cases where the pathogen passes through the surface lining of the gut, infection can spread to the bloodstream (Chin 2000, Hunter 1997). *Salmonella* species are as susceptible to chlorine disinfection as is *E. coli* (Hrudey and Hrudey 2004).
Ultimately, this outbreak resulted in 434 reported cases of gastroenteritis, including 124 laboratory-confirmed cases of salmonellosis, with 20 hospitalizations and 1 death (Ailes et al. 2013). A telephone survey estimated that a total of 1,300 were ill during this waterborne outbreak. Of those who reported diarrheal disease (21 percent of those surveyed), 29 percent reported illness with potential long-term health consequences.

The insurer for the City of Alamosa paid $360,000 to 29 Alamosa residents, including the widow of the deceased 54-year-old male (Wilson 2010). With the out-of-court settlement, the City of Alamosa issued a press release stating that it continues to “dispute that there was any negligence on the part of the City for the outbreak.” A median estimate (Ailes et al. 2013) of costs experienced by residents and local businesses was $1.5 million (range $197,000 to $6 million), and an estimate of total costs including governments and public agencies was a median of $2.6 million (range $1.1 million to $7.8 million). The progress of the epidemic is illustrated in Figure 2-16.

Questions to Ponder

1. Would this outbreak have occurred if even a modest chlorine residual had been provided and maintained throughout the Alamosa distribution system?

2. How useful was the total coliform monitoring in this system for ensuring safe drinking water given the flaws that were allowed to develop in the distribution system?

3. Has your distribution system inspection program ensured that the system is free of cross-connection hazards and the numerous other contamination vulnerabilities discovered in this system?
4. Is your distribution system maintenance program adequate to avoid this kind of storage contamination?

5. In particular, do you perform regular storage tank inspections and cleaning?

6. Do you have a utility network that could come to your assistance in an emergency like this?

7. How could this situation have been handled better?

**Lessons**

1. Very little contamination was likely necessary to trigger this outbreak, a reality with fecal material, which can contain huge numbers of pathogens. Water systems, particularly those that do not chlorinate, must be incredibly vigilant about system integrity.

2. Just because it has not happened yet does not mean it will not happen tomorrow. The problems leading to this outbreak in Alamosa were present for many years, but then one day in 2008 a very large outbreak began.

3. Serious drinking water contamination can occur without any warning signals in a minimal-cost system such as this one that the City of Alamosa accepted in 2008.

4. If a water utility is going to operate with no or only limited disinfection, it faces a major risk of waterborne disease and must operate to minimize such risks.

5. Having high-quality water delivered to your distribution system does not ensure that contamination capable of causing a severe outbreak will be avoided.

6. Distribution system vulnerabilities must be identified regularly.

7. Distribution system maintenance must address all potential vulnerabilities to contamination.

8. Water utilities must be prepared to respond to emergencies, including having a functional Emergency Response Plan and participation in a mutual aid network with other utilities.

9. Even in a major disease outbreak like Alamosa, to which major investigative resources were applied, finding a specific, detailed cause of the contamination may not be possible because of the time passage between contamination and the occurrence of illness that triggers the investigation.
In March 1995, the Village of Freuchie (Figure 2-4), about 50 km (30 mi) north of Edinburgh in Fife, Scotland, had a population of about 1,100 (Fife Regional Council et al. 1996, Jones and Roworth 1996). The community drinking water supply was part of a regional treated water system that provided service through a pressure-reducing valve from a reservoir (540 m³) located on a hill to the west of the Village (Figure 2-5). The system pressure was reduced from 720 kPa (90 psi) to 450 kPa (50 psi) immediately upstream of the Freuchie service delivery area.

Operational Experience

At 9:55 a.m. on Friday, Mar. 10, 1995, a consumer phoned the district Council (the regional water utility) to complain about poor water quality (discoloration) and being ill, possibly because of the water. The caller was located in the Christiegait district (water service zone 1 on the eastern side of Freuchie, Figure 2-5). The first call was followed quickly by three more complaints about discoloration between 10:15 and 11:40 a.m. One of these
Figure 2-4  Village of Freuchie, Fife, Scotland (photo by Richard Allan, reproduced with permission)

Figure 2-5  Freuchie water distribution schematic showing sites of first complaints (sites boxed and shaded) (adapted from Jones and Roworth 1996 with permission © 1998 Elsevier)
was within 100 m of the first complaint in Christiegait and the other two were within 300 m and 400 m, respectively (North Street and Eden Valley Cottage, Unthank), in water service zone 3. Sampling was initiated and a decision was made to begin flushing the relevant service mains by 12:45 p.m. Samples from complainants’ supplies were delivered to the laboratory at 1:30 p.m. on Friday. Chlorination was increased slightly at the service reservoir at 2:50 p.m.

At 3:50 p.m., an additional call about discoloration was received from another home in Christiegait, but the utility personnel judged this complaint to have possibly been caused by the mains flushing in the area. A Water Inspector returned to the Christiegait district to perform further flushing.

The samples from both supply zones (1 and 3), as received at the laboratory, were cloudy with some visible brown sediment. No sampler or laboratory comments about sample odor were reported in the investigative report. Chemical analyses commenced at 3:45 p.m. and bacteriological tests were initiated. Initial chemical results, obtained as early as 4:00 p.m., indicated that the water samples were more likely to be groundwater than the normal Freuchie surface water supply. Final analytical results for samples from complaints for the first two affected water service areas showed alkalinity and hardness concentrations approximately three times and nitrate concentrations more than five times typical mains water for Freuchie. The alkalinity and hardness values were indicative of groundwater supplies in the region, despite the absence of groundwater in the supply to the Freuchie service reservoir.

At 4:30 p.m., the Water Operations Engineer for the region was informed of the findings, and the locations of all complaints were plotted on a distribution system map. The service reservoir was sampled to determine whether any contamination was evident in the water supply coming to Freuchie through the primary service main to the west. Given the location of the complaints, a 10-cm (4-in.) main running to the eastern end of the Village came under suspicion as the location being contaminated. This main terminated east of the Village beyond a connection provided to a local farm that had been served by the community water supply for a vegetable washing and packaging process plant (Figure 2-6), employing about 200 persons on a three-shift operation. This vegetable processor was now thought to have its own groundwater well, raising the possibility of it being a source of contamination for the Village water supply. At this point, the discoloration observed was attributed to flow reversal in the service main because the involvement of groundwater would not have explained the turbidity and off-color. Likewise, although it is not clear if the nitrate concentrations were known at that time, no explanation was evident for the elevated nitrate levels that were eventually reported.

At about 5:00 p.m., the Principal Chemist for the regional water supply called the vegetable processor to confirm whether it was using a groundwater well supply. He was told that the company did have such a supply, but the pump was being serviced, it was not operational, and it had been out of service since Sunday, Mar. 5. Although this answer did not fit the theory at that time of groundwater contamination from the vegetable processing plant, a decision was made to close a main line valve west (on the regional supply side) of Christiegait to determine if that main was the only source of water to this district where 3 of the 5 complaints had originated. This action revealed continued flow from a hydrant in Christiegait following valve closure, indicating another source of water flow into the eastern end of the community distribution system.
Figure 2-6  Vegetable processor (photo by Richard Allan, reproduced with permission)

A Water Inspector was sent to the vegetable processing plant at 5:45 p.m. to shut the valve serving this operation. While closing the valve, the inspector noticed that the water meter was running backward, indicating that water was running from the vegetable processing plant to the Village water main. Once the valve was completely closed, water flow at the hydrant in Christiegait ceased. With the system now believed to be isolated from the suspected source of contamination, further flushing of the system from the service reservoir commenced.

What Actually Happened

Having obtained clear evidence that water from the vegetable processor was flowing back into the community water main, a Water Inspector and the Regional Engineer visited the company at 6:15 p.m. to investigate the source of the backflow. They discovered that the facility had not been using their on-site well, but had been drawing untreated water from the adjacent creek (Freuchie Burn) for use as a preliminary vegetable wash with final vegetable washing being done using the Village disinfected water supply. This use of raw creek water had occurred since about 1:00 p.m. on Monday, Mar. 6, that is, for more than four days by Friday.

The Principal Engineer was notified of this situation at 6:45 p.m. because serious contamination of the community water system was becoming evident. The areal extent of contamination of the community distribution system and the degree of contamination was not yet known. However, because the raw water withdrawal point used by the vegetable processing facility was immediately downstream of the Village sewage treatment plant outfall, Council staff recognized the potential for serious contamination of drinking water and resulting public health risk.

Decisions were quickly made to

1. Issue a boil water advisory for drinking water use to everyone in the Village of Freuchie by means of door-to-door visits and written notification.
2. Flush the entire distribution system downstream (east) of the pressure-reducing value that was down-gradient of the storage reservoir.
3. Increase chlorination of the water provided to the system.


The Director of Public Health Medicine of the Fife Health Board was notified of the situation at 7:00 p.m. and he indicated support for the measures proposed, adding that residents who were ill should be encouraged to seek medical attention. He contacted the three general practice medical clinics in the area to inform them and to inquire about any patterns of illness observed. Two of these clinics reported a number of cases of illness typified by abdominal pain, “flu-like” illness, and diarrhea. The clinics were advised to pay particular attention to groups of residents who may be more vulnerable to gastrointestinal pathogens (e.g., very young and elderly).

The Deputy Director of Environmental Health learned of a resident suffering illness who attributed the illness to consumption of Freuchie drinking water, so he contacted the Principal Chemist at about 9:00 p.m. to receive a full appraisal of what was known, what steps were being taken to respond, what was proposed to search for a cause of illness, and what steps were being taken to protect residents from additional health risk. Upon being notified of the advice to boil water, some villagers phoned the emergency number provided to report that they had been ill for 3 to 4 days. They were advised to contact their doctors.

The local police were advised about the incident and the response actions being taken. Off-duty community water personnel were called in for briefing about the contamination episode and to assist with the door-to-door notification. Additional samples were taken before the complete system-flushing program was launched.

Although it was believed that all houses had been visited by 11:45 p.m. on Friday, additional houses that had been missed were identified on Saturday, Mar. 11. Contact was made with the Social Work Department to determine if there were any special needs clients who could be identified. Additional chemical sampling was undertaken to verify that the Village distribution system was now clean. By noon on Saturday, it was evident from contact with local general medical practitioners that cases of illness were into the dozens. Public health professionals provided advice to physicians about collecting stool samples from ill patients. A press statement about the situation was issued, but in response to numerous calls inquiring into what had happened, officials had to advise that it was too early to provide any details about possible causes.

The Water Inspector and Regional Engineer returned to the vegetable processing plant at about noon on Saturday, Mar. 11, to take photographs and gather further evidence on what had happened. They determined that the private well supply pump had failed on Sunday, Mar. 5, and that the vegetable processing facility had reverted to a practice in place prior to 1992 whereby raw water from the creek (Freuchie Burn) was used for a preliminary vegetable wash. This preliminary raw water wash system, used prior to implementation of the well water source, was originally completely separated from the final vegetable wash system that was drawn from the Freuchie community water supply (Figure 2-7a).

Samples collected from the original consumer complaint locations (Friday morning) showed indicator *Escherichia coli* exceeding 2,000 per 100 mL, confirming massive sewage contamination of the drinking water system in both affected distribution zones (1 and 3). By inference, zone 2 must have been affected because it was served by the main between zones 1 and 3 (Figure 2-5).
On Sunday, Mar. 12, all samples except for two properties were found to be free of bacteriological contamination, but the boil water advisory was kept in place and more samples were collected. Many residents began complaining about the chlorine taste in their water—with residuals measured between 0.4 and 1.0 mg/L. This suggests residents had become accustomed to a lower chlorine residual because consumers can normally tolerate such levels without complaints if they become used to such levels (< 1 mg/L).

On Monday, Mar. 13, the Water District Inspector returned to the vegetable processor and determined that this facility had reconnected to the Village water main and opened the valve without any authorization. The District Inspector was instructed to shut off the water supply, but the vegetable processor immediately appealed that decision, requesting water service to allow continuation of its business and to satisfy its vegetable supply contracts. The Council sent three additional personnel to inspect the site. Reconnection was approved for 24 hours, after confirming that no further cross-contamination from the creek could occur. Apparently, in this jurisdiction, a water authority had no power “to refuse a public water supply if the Conditions of supply have been fulfilled” (Fife Regional Council et al. 1996).

Further investigation into events revealed that between 1990 and mid-1992, the company had two completely separate water systems: the preliminary wash system that drew raw water from the creek (Freuchie Burn) and the final vegetable wash system that used the Village main’s water (Figure 2-7a). In late 1990, the vegetable processor had applied for an increase in water supply from the Village system. Following inspection of the piping, flow testing, and some resulting modifications, a separate larger-diameter connection to the Village water main was provided on Jan. 24, 1991. These modifications complied with all water bylaw requirements at that time. In mid-1992, the company drilled a well supply and used this for the vegetable pre-wash, replacing the use of raw water from the creek.

Then, in mid-1993, the facility decided to use the well water supply for both the pre-wash and the final rinse, thereby ceasing its use of the Village water supply. During this period of using only well water, a plumbing connection was apparently added between the prewash and final wash systems (Figure 2-7b). At this time, without notifying the Council, the company apparently removed a pipe that connected its system to the Village main, but continued to pay the standing charge for its water meter.

In the summer of 1994, the company diverted the creek (Freuchie Burn) about 20 m to the west to avoid polluting it with runoff from a paved area around its site. In performing this diversion, the company uncovered a buried pipe carrying treated sewage effluent to a discharge point downstream of its premises. In an ironic turn of events, given what ultimately happened, the company applied to authorities to have this effluent outfall moved upstream of its intake to accommodate the creek diversion project (Figure 2-7c).

At about 8:00 a.m. on Sunday, Mar. 5, 1995, the company experienced a pump failure that interrupted its on-site well water supply, so it reconnected to the Village water supply and used this source exclusively for both pre- and final vegetable washing until about 1:00 p.m. on Monday, Mar. 6. At that time, it began pumping raw creek water into the plant for the preliminary wash, using the feed pipe from the well. Two serious flaws arose with this situation because the creek raw water intake location was now downstream of the Village sewage treatment plant outfall and the preliminary rinse and final rinse systems were still connected (Figure 2-7c). The final factor contributing to the backflow contamination was that the system pressure for the vegetable processor reached 620 kPa (75 psi) compared with the Village mains pressure, after the pressure reducing value, of 450 kPa.
(50 psi). This pressure differential and the apparent absence of a functional backflow prevention device allowed water from the vegetable processor to flow into the Village of Freuchie water main. Furthermore, the opening of hydrants for the purposes of flushing, as was done after the initial complaints, further reduced distribution system pressures by an increment of 55 to 110 kPa (8 to 16 psi), thereby increasing system contamination from the vegetable processor while attempting to respond to the original complaints.

Subsequent calculations based on the reverse flow of the water meter, taking into account the amount of mains water used before the raw creek water supply was connected on Mar. 6, indicated that for the four days of cross-contamination, the contaminated flow was up to 10 percent of the total Village water supply, being proportionally higher in water zones 1, 2, and 3 and lower in zones 4 and 5 (Figure 2-5).

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Analyses of the contaminated water samples from households that lodged complaints revealed extreme bacterial contamination, but otherwise, only turbidity and iron were found to be outside acceptable water quality conditions. This reality illustrates the limitations of water quality monitoring for being able to warn of health-related water contamination. Consumer complaints generally did not occur until days after most consumers were already infected. Based on consumer interviews, some individuals in zone 1 and zone 3 had noticed a slight yellow color as early as Monday, Mar. 6, but had not complained. No taste or odor complaints were reported. Subsequent analysis also noted that turbidity in the raw creek water was low until Mar. 9 when building work at a local garden center caused increased creek turbidity.

Despite being aware of the company’s creek intake being located below the Village sewage treatment plant effluent outfall because the vegetable processor had requested that outfall relocation, correspondence from this food processing company readily indicated that it did not believe that the sewage effluent adversely impacted the raw creek water in any way that could pose a health risk from the vegetables washed with it (Fife Regional Council et al. 1996; appendix 12). Dirty wash water following its use in the vegetable washing operation was drained to land and was not a factor in this contamination episode.

The Consequences

The community of about 1,100 (968 of whom returned questionnaires about their health) had 765 residents who reported illness, 711 had gastrointestinal illness and 633 were defined as “cases” because they were experiencing diarrhea, vomiting, or abdominal pain with first onset between Mar. 6 and Mar. 24, 1995 (Jones and Roworth 1996). Of these self-reported cases, only 6 occurred after Mar. 15, with a peak of 149 cases occurring on Mar. 10, the day when phone complaints to the water utility had begun (Figure 2-8).

Figure 2-8  Time course of illness cases among Freuchie residents (Fife Regional Council et al. 1996, with permission)
The first case was admitted to hospital and two other cases were referred to the infectious disease unit in Dundee (25 km north) on Tuesday, Mar. 14. There were two cases of hemolytic uremic syndrome (HUS) and both children recovered. In total, five individuals were hospitalized and all recovered. The attack rate (percent of cases among exposed population) was 80 and 81 percent in zones 1 and 2, decreasing to 43 percent in zone 5, furthest removed from the source of contamination (Figure 2-5). Although approximately 70 stool samples were collected, only eight cases were confirmed for Campylobacter spp. infection (seven being *C. jejuni*) and six cases confirmed for *E. coli* O157 infection, two of which subsequently developed HUS. Two of the *E. coli* O157 cases were judged to have resulted from person-to-person contact, rather than primary infection from the drinking water supply. The first case of *Campylobacter* infection was confirmed on Wednesday, Mar. 15, and the first case of *E. coli* O157 was confirmed on Friday, Mar. 17. These observations demonstrate the inevitable time delay and lack of specificity of clinical evidence for detecting a large community waterborne disease outbreak in which a majority of residents became ill.

Fortunately, given the severity associated with *E. coli* O157 infection in outbreaks like Walkerton (chapter 3), no fatalities resulted from this outbreak, but it is clear that a substantial majority of the residents were made ill. Notably, the majority of the exposed population were ill by the time that the contamination was discovered, and more than 90 percent likely had been infected before remedial measures (flushing, increased chlorination, and boil water advisory) could have shown any protective effect.

On Wednesday, Mar. 15, the metered connection supplying the vegetable processing plant was removed, thereby ending any access of this facility to the Village water supply. Written statements from the company were issued on Mar. 13, 15, and 16 (Fife Regional Council et al. 1996; appendices 12, 13, and 14). These statements explained the actions of the company from its perspective and explained that the wash water, after it had been used for the first vegetable wash, drained away and could not have reached the Village water supply. Consequently, used wash water was not responsible for the contamination. However, the public health risk from using untreated creek water was apparently not recognized by this food processor, as indicated in the company statement (Fife Regional Council et al. 1996; appendix 13): “There was no reason to suspect that the water from Freuchie Burn was not potable. Tests took place in October which confirmed that the water was perfectly safe. This is in spite of the fact that, last summer, the location of the sewage outfall from the Freuchie sewage pipe was relocated upstream of the plant.”

In December 1995, the vegetable processing company pleaded guilty to charges of contravening the Health and Safety at Work Act, in that it “failed to conduct their business in such a way as to ensure that persons not in their employment were not exposed to risks to their health” (Fife Regional Council et al. 1996). The company was fined £60,000. At the Court hearing, the lawyer for the company advised that when its well supply pump had failed, it had retained a plumbing contractor to reconnect to the Village water supply, but the contractor did not install any backflow prevention device. No evidence was reported about regulatory requirements for installation of a backflow prevention device.

*Campylobacter* species include a range of bacterial pathogens that maintain a wide range of animal hosts, including domestic and wild animals. Birds provide a major source of human infection, including risk through undercooked, contaminated poultry, but these pathogens are also commonly found in sewage effluent (Hrudey and Hrudey 2004). *Campylobacter* produce acute gastroenteritis with diarrhea, which may be either profuse and watery or may contain blood and mucus. Diarrhea may be of variable severity and is often accompanied by abdominal pain (which may be severe enough to mimic appendicitis), headache, fever, nausea, and vomiting. The disease appears with sudden onset and has a typical incubation period of 2 to 5 days within a range of 1 to 10 days (Hrudey and Hrudey 2004).
As a result of this experience, the Water/Drainage Division of the local Council drew up a list of all water users believed to have dual water systems. This listing was followed up by inspections to ensure all water service bylaws were followed and that such customers were informed about the dangerous consequences of cross-connections. Consideration was also given to whether Council actions should be triggered if water consumption by a customer dropped to zero for an extended period.

Questions to Ponder

1. Would your system have been able to respond as quickly and completely as the response described in this case?
2. Does your water system Emergency Response Plan (ERP) address all of the actions (e.g., rapid sampling and analyses of water from complainants, review of distribution patterns, estimates of possible contaminated water volume, inspection of suspected source, rapid call of boil water advisory, door-to-door notification, alternative water supply, etc.) that were followed in this case? Are your ERPs tested in desktop or mock exercises?
3. What is your distribution system sampling protocol? Could it have detected an incident like this before the consumer complaints and community illness emerged?
4. Do you have low-pressure alarms to signal if distribution system flushing is lowering system pressures too drastically?
5. Do you have a routine cross-connection prevention program in place for your distribution system? Does your program include inspections with enforcement of installation and maintenance of backflow prevention devices?
6. Do you know enough about all of the industrial–commercial users of your water supply and their potential for causing system contamination by backflow? How often do you check on them?
7. Does your water utility have the legal authority to shut off all connections to a water user upon suspicion of that user having contaminated your water system?
8. Do you have an effective communications strategy to inform customers of their responsibilities to avoid cross-connections?
9. Should the Council (the water utility) have noticed the cessation of water use by a major water user like the vegetable processor, once the meter was read, and inquired about the implications of that change in practice?
10. Should more system samples have been taken of the water during the investigation, particularly when the backflow was discovered? Samples can always be stored for later chemical analysis if lab capacity is strained, but it is not possible to go back in time to take samples at relevant locations after conditions have changed that may be critical to explaining a cause of contamination.
11. If you are on a regional water system, do you have the local resources (including laboratory access for water analyses) or other backup resources to investigate a problem like this?
12. How could this situation have been handled better?
13. How else could this contamination episode have been prevented?

Lessons

1. Consumers can, for some time, tolerate microbial contamination sufficient to cause illness without launching complaints.
2. Generally, most consumers cannot be relied upon to complain quickly about water quality because they may be too busy, otherwise reluctant to do so, or simply not know how to complain about their water service.
3. Responses to a contamination episode, even if very rapid and apparently sound, are usually too late to prevent illness. Reducing pressure by commencing flushing may result in contamination being worsened before the cause of contamination is discovered.
4. Performing simple and quick water chemistry analyses can often provide very useful information when trying to investigate a contamination episode.
5. Often the whole relevant story will not come out in early discussions between a water user and the water provider. In this case, the vegetable processor advised that it had not been using its well for over four days, but the fact that it was using untreated creek water for much of that time was only reported later. Matters that may (or should) be obvious to professionals trained in water quality are much less likely to be understood by water users.
6. Despite the obvious inference that using creek water downstream of a sewage effluent outfall could pose a risk to the quality of food processing, let alone the cross-contamination that it did cause, water professionals cannot expect others to recognize such hazards. This reality makes it all the more essential for water professionals to be extremely sensitive to all such threats.
7. System changes over time (changes in plumbing, i.e., Figure 2-7) can lead to unintended consequences, such as allowing backflow in this case.
8. Otherwise competent trade contractors cannot be relied upon to recognize water contamination risks, meaning that water utilities need to validate the quality and safety of all construction work performed for it.
9. Strange things often do happen possibly with unpredictable consequences. In this case, the decision by the vegetable processing company to relocate the Village sewage treatment plant outfall upstream of its intake point for raw creek water played a major role in the outbreak.
10. Chlorine taste is often a source of consumer complaints when chlorine dosage changes, even in this case where increasing chlorination was making seriously contaminated water safer for consumers.
Chapter 5

Case Studies of Close Calls

STRATFORD, ONTARIO, CANADA, 2005

The City of Stratford, Ontario, home of the internationally acclaimed annual Stratford Festival, launched in 1953 originally as a summer festival of Shakespearean theater, is an idyllic, tourist-oriented community of more than 30,000 located on the Avon River in rural Perth County in southwestern Ontario, 150 km west of Toronto.

The Stratford water supply is provided by a total of 11 wells, 6 pumping stations, 2 water towers, and a 7.5-ML reservoir. All of the City’s wells provide high-quality source water and are rated as secure groundwater (not under the direct influence, i.e., not GUDI); 6 of the 11 wells are located in a well field in the northeast quadrant of the City (Figure 5-1) that is pumped into the reservoir after treatment with gas chlorine and sodium silicate for iron sequestering. The remaining 5 pump stations (wells) are located throughout the City, each equipped with chlorine gas for treatment.

Operational Experience

The entire basis for this case study was drawn from the generous sharing of a PowerPoint presentation by Joe Salter, the Manager of Water Treatment and Distribution for the City of Stratford (J. Salter, pers. comm.*). This presentation has been given numerous times for water industry personnel, including for the Ontario Water Works Association and for AWWA’s annual ACE conference in 2007. We hope more water professionals will be willing to share these kinds of presentations in the future.

On Monday, Mar. 7, 2005, at 10:20 a.m., a complaint call was received at City Water Division noting that “pink foaming water” was flowing from taps at a house next to a fire station in southwestern Stratford (Figure 5-1, Figure 5-2). At 10:30 a.m., Stratford’s Water Supervisor was able to confirm the accuracy of this complaint. Given the nature of the

* Mr. Joe Salter; email messages with author and PowerPoint presentation, The Need for Back Flow Prevention Programs, with review and discussion of draft text based on presentation, 2013.
Figure 5-1  Map of Stratford showing locations relevant to this case study (Joe Salter 2013, City of Stratford, used with permission)
problem being reported, colored, foaming contamination of the water (Figure 5-3), suspicion focused on a car wash across the street from the complainant’s house.

At 11:00 a.m., the Water Supervisor visited the car wash located 0.5 km from the Water Division Engineering and Public Works Department office and he shut off the City water supply to the car wash (Figure 5-2). The Water Supervisor spoke with the manager of the car wash to determine that staff had been engaged in high-pressure cleaning of their facility that morning. One of the customers of the car wash had complained to the staff that morning that the rinse cycle on the car wash contained pink foam. The foaming contamination was attributed to a product called Hyper Concentrate Foaming Brush Detergent. The Water Supervisor obtained a material safety data sheet (MSDS) for this detergent product. This MSDS revealed that the active ingredient in this product was 2-butoxyethanol: while listed in Canada as “very toxic,” it is only toxic at very high exposure but it is soluble in water. The ingredient 2-butoxyethanol is clearly a noxious substance that is unacceptable as a contaminant in a potable water supply.

At 11:07 a.m., the Stratford Water Supervisor called the Perth District Health Unit, with its main office only a few blocks away from the site of the initial incident, and reported what had happened, including advising health unit staff about having the MSDS. At the same time, City personnel reported the incident to the Spills Action Centre of the Ontario Ministry of Environment and described the actions that the City was taking.

By 11:30 a.m., distribution system personnel began flushing the three hydrants closest to the car wash (Figure 5-4). These were opened to create a high demand and draw water back to this area preventing the spread of contamination throughout the distribution system. The hydrants were run open for 72 hours.

At 11:40 a.m., the City Director of Engineering and Public Works and the Manager of Water Treatment and Distribution met with the Medical Officer of Health while other staff from the Health Unit simultaneously teleconferenced with the Ontario Ministry of Environment regional office in London. Based on an understanding (from the time that the Water Supervisor first attended the car wash, i.e., about 11:00 a.m.) that the contamination had been caused by an unapproved high-pressure cross-connection without
Figure 5-3  Pink foaming detergent contamination of water in a toilet bowl at the car wash (Joe Salter 2013, City of Stratford, used with permission)

Figure 5-4  Distribution system flushing locations (Joe Salter 2013, City of Stratford, used with permission)
a functional backflow valve and, given the noxious characteristics of the contaminant apparent from the MSDS, the need for a drinking water advisory was agreed on.

At 12:00 noon, a drinking water advisory was issued by the City and its Emergency Plan was called out. The advisory stated:

A Drinking Water Advisory is in effect for the City of Stratford. The Ministry of Environment and public utilities are working on the problem. The Advisory is due to a spill into the system.

Until further notification, all residents of Stratford are urged NOT TO CONSUME THE WATER. As well, residents should not feed the water to pets, or use the water for bathing or washing.

Residents will be told when the problem is solved. The Medical Officer of Health, or a Public Health Inspector, is the only person who can lift this advisory.

If you are sick, seek medical assistance by going to Stratford General Hospital.

The City of Stratford will be supplying drinking water to residents. More information will be released as it becomes available.

At 1:00 p.m., the Community Emergency Control Group* was convened. Calls were made to all Stratford restaurants with the instructions:

Any food or drink prepared today, March 7, using tap water must be discarded and not used. This includes produce washed in water, all beverages prepared with water, food that water has been added to.

The food premise must stop using tap water immediately. Please bag all taps that are accessed by the public.

A food premise can remain open to the public if:

• there is access to bottled water for food and drink preparation
• you can provide customers with hand sanitizer in the washroom
• employees can wear gloves

If these conditions cannot be met, the Perth District Health Unit is advising food premises to cease operation until further notice.

The City of Stratford will be supplying drinking water shortly. The Health Unit will inform you as soon as it is available.

Simultaneously, calls were made to the nearby communities of Waterloo (45 km away) and St. Marys (20 km away) to arrange alternative bulk water supplies.

At 1:30 p.m., the City had mobilized to deploy staff to disseminate by multiple means the Do Not Use Water Advisory. Within approximately the three following hours, flyers alerting residents to the situation were delivered to all ~13,000 homes in Stratford by firefighters and other municipal workers.

* Designates or Alternates: Mayor, Chief Administrative Officer (Operations Officer), Police Chief, Fire Chief, Director of Engineering and Public Works, the Manager of Water Treatment and Distribution, President of Festival Hydro Inc., Medical Officer of Health, Director of Social Services, Director of Emergency Medical Services, Public Information Coordinator, and Director of Community Services.
What Actually Happened

City plumbing inspectors discovered that an unauthorized cross-connection between the car-wash plumbing system and the City water plumbing system had inadvertently been opened, allowing car-wash system water to flow back into the City’s distribution system (Figure 5-5). A total of 2,300 to 2,700 L of contaminated water from the car wash was estimated to have backflowed into the City system.

At 4:00 p.m., the City and Health Unit held the first news conference. By this time, the story was already being reported widely in the national media. By 5:00 p.m., the first of five City bulk water depots was opened using water shipped by tanker from Waterloo and St. Marys. Hundreds of residents lined up to fill containers with water. Water was delivered to the Stratford General Hospital and nursing homes. Elective surgeries were canceled and dialysis patients were directed to other jurisdictions. Local stores experienced a run on sales of bottled water, and local schools were closed for the next day.

At 6:00 p.m., water samples were taken and shipped to the Ministry of Environment laboratory in Toronto. At 9:00 p.m., the Health Unit released an updated notice stating the following:

The Perth District Health Unit has learned that approximately 5 gallons of Hyper Concentrate Foaming Brush Detergent, containing the chemical 2-Butoxyethanol, has been released into the Stratford drinking water distribution system earlier today. This led to the issuing of a Drinking Water Advisory, which remains in effect.

Testing for both the chemical contaminant and possible bacterial contamination has been done, under guidance of the Ministry of the Environment. Results of testing are expected to begin arriving later tonight. It will take 48-72 hours before testing has been completed. The Drinking Water Advisory will be in effect until tests show that the water is safe to drink. 2-Butoxyethanol is a solvent found in industrial and household cleaners, paint thinners and strippers, enamels, lacquers and varnishes.

People who swallow large amounts of cleaning agents containing 2-butoxyethanol have shown breathing problems, low blood pressure, low levels of hemoglobin, acidic blood and blood in the urine. The chemical is an irritant and has no long-term or chronic effects. It is not classified as a carcinogen.

In the small amount that entered Stratford’s water system, it might be possible that exposed residents experience mouth and throat irritation and stomach upset. It is expected that testing will show that the City’s swift action has prevented harmful levels of the chemical to accumulate in the city’s water supply. However, in the meantime, residents are being asked by the Medical Officer of Health to take precautions by not drinking the water. 2-Butoxyethanol is completely soluble in water and is effectively removed by actions that the city has undertaken.

The Emergency Department at the Stratford General Hospital has been notified and so far there have been no sick residents reported to the health unit.

At 9:45 a.m. on Tuesday, Mar. 8, the second day of the incident, the Community Emergency Control Group and the Ontario Ministry of Environment held a conference call to discuss water monitoring and testing issues.

At 10:30 a.m. at the second news conference, the Health Unit put out another release to advise that the drinking water advisory was now limited to a boil water advisory because
analyses of samples taken on Mar. 7 showed that the City was free of any detectable 2-butoxyethanol. It was necessary to keep a requirement for boiling water because the microbiological safety of the compromised water system could not yet be verified.

At 1:00 p.m., the City delivered information on the water advisory and flushing procedures for residents and businesses (Figure 5-6).

At 8:00 p.m., the first microbiological tests results were received and they were found to be clear of any indicators of contamination.

On Wednesday, Mar. 9, the third day of the incident, at 9:00 a.m., a news release was issued to announce that the Medical Officer of Health expected to lift the boil water advisory that evening. At 7:40 p.m., after the second microbiological test results were received and confirmed as free of detection for microbial indicators, the boil water advisory was lifted. At 9:00 p.m., a final teleconference was held among Ministry of Environment, Ministry of Health, and City of Stratford officials to debrief.

On Mar. 10, City officials were occupied with further dealings with the press and public inquiries. At 3:00 p.m., the Community Emergency Control Group debriefed with the related agencies.

The Consequences

The water emergency lasted 56 hours. A total of 80 volunteers (not staff) were involved, contributing 640 hours of volunteer time for deliveries. A total of four series of flyer deliveries were done to homes (13,161 addresses × 4). Water was delivered to residents in 391 homes with 24,192 cases of bottled water, totaling 199,584 L given out. A total of 825 hours were devoted to manning water depots. The total estimated cost to the City was $188,000.

The website hits during the few days of the Advisory period totaled 4,506 versus the normal rate of 450–550/month. The call center began Monday afternoon and was staffed through until Tuesday evening at 10:00 p.m., a total of 33 hours straight. The call center started up again on Wednesday 8:00 a.m. to 10 p.m., but because of the high total volume of calls received, the City was unable to track the total number of calls received. The call center was staffed for 47 hours, and 391 calls alone were requests for bottled water deliveries. Public inquiries addressed topics such as flushing procedures, water softeners and water heaters, pet safety, questions about use of water, and compensation concerns.
WATER USE ADVISORY

Water Use Procedures

- Run all cold water taps for 5 minutes.
- For larger multi-unit residences, it will be necessary to run water for a longer time period. Water should run until a constant temperature is noticed; this will indicate that the water is from the water main.
- Once all cold water lines are flushed (step 1 above), run all hot water taps until water cools. Time how long it takes to do this step and then repeat it again. By doing this you will be flushing your hot water tank twice.
- Regenerate water softener, if you have one.
- If you have fiber or carbon water filters, consideration should be given to replacing the cartridges.
- If you have a reverse osmosis system, contact the supplier or manufacturer for advice. In the meantime, you could bypass the reverse osmosis filter.

Bathing/Showering

Adults, teens, and older children can use tap water for baths and showers. Small children can be given sponge-baths instead of tub baths or showers. Do not swallow any unboiled water used for showers and baths.

Handwashing

Wash your hands as you normally do: under warm running water with soap.

What Is a Boil Water Advisory?

During a Boil Water Advisory, you can continue to use the safe drinking water being supplied at locations around the city, or boil your water at a rolling boil for at least one minute. Use boiled or bottled water to:

- Drink
- Gargle, brush your teeth, or rinse dentures
- Feed to pets
- Wash fruits, vegetables, and other food
- Prepare food
- Make ice, juices, pudding, and other mixes
- Make baby food or formula.

Figure 5-6  Notification for residents and businesses about the water advisory* used for this specific incident (Joe Salter 2013, City of Stratford, used with permission)

*More general advice on such advisories is available (CDC toolbox): http://www.cdc.gov/healthywater/emergency/dwa-comm-toolbox/)

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How Long Will the Boil Water Advisory Last?
The Perth District Health Unit is awaiting further test results to ensure that the water is free of any harmful bacteria and is safe to drink. We expect these results by the end of the week. When the results are received, the Medical Officer of Health will lift the Advisory.

Can I Bathe and Shower With Tap Water?
When bathing or showering, it’s important not to swallow any water. For this reason:

- Adults, teens, and older children can use tap water for baths and showers.
- Wash small children with a sponge or cloth instead of tub baths or showers.

Can I Wash My Hands with Tap Water?
Yes, you can wash your hands as you normally do under warm running water with soap.

I Have a Water Filtration Device Installed. Does This Make the Water Safe for Drinking or Cooking?
No. Filtered water should also be brought to a rolling boil for one minute before drinking or using it for cooking. Consider replacing your filters.

What About My Laundry?
Under a Boil Water Advisory, tap water may be used for doing laundry.

How Do I Wash My Dishes?
Use boiled or bottled water to hand wash dishes in the sink. If you have a dishwasher, the Health Unit recommends that if your dishwasher has a “High Temperature” cycle, then it is safe to use. If your dishwasher does not have a High Temperature cycle, after finishing the cycle, soak dishes for one minute in a solution of 30 mL (1 ounce) of bleach mixed with 13.5 litres (3 gallons) of lukewarm water. Let dishes air dry.

What If I or My Child Drinks Tap Water by Mistake?
If you or your child develops any symptoms, such as vomiting, fever, and/or diarrhea, seek medical attention at Stratford General Hospital.

What About Indoor Swimming Pools in Stratford?
Swimming pools are currently closed and will remain closed until test results from the Ministry of the Environment show the water is safe.

How Do I Regenerate My Water Softener?
Check your manual book for instructions or call the store where you purchased it or the manufacturer for instructions.
The company running the car wash and the owner were fined a total of $75,000, after each was convicted of violating section 20(1)(c) of the Ontario Safe Drinking Water Act (2002). The City received $100,000 as the result of an out-of-court settlement between the corporation and the owners of the company responsible toward the municipality’s out-of-pocket expenses associated with the emergency.

A number of lessons were learned by those directly involved in this incident, including:

- Vital benefit of strong leadership from the Mayor and Chief Administrative Officer
- Importance of a having a good emergency plan as a foundation for response
- Importance of having solid partnerships with health officials and the Drinking Water Regulator
- Water being supplied within 5 hours of the drinking water advisory
- Water being delivered to people in need (391 deliveries)
- Benefits of having a “one-stop shopping” phone line
- Excellent assistance from the region of Waterloo and nearby community of St. Marys
- Value of providing useful information on the City website including having a “hot button” to navigate to important information
- Opportunity to draw on community spirit with volunteerism
- Critical importance of communications with the public

Based on this experience, some steps have been taken to improve preparedness for future emergencies, including:

- Prearrange GIS flyer routes—keep updated
- Ensure internal communications person attends Emergency Control Group
- Ensure hospital staff attend Emergency Control Group
- Ensure “immediate” internal communications
- Set up complete one-stop shopping for calls including all parties (e.g., health and water)
- Ensure careful preparation for press conferences
- Officially declare an emergency
- Formalize incident management system
- Use community email systems (e.g., chamber membership)
- Look at emergency broadcast system
- Look at more emergency generators
- Finalize supplementary emergency plans
  - Integrated emergency communications plan
  - Social services plan

A critical point for other communities involves the prevalence of cross-connection risk. A review of six 2005 Ministry of Environment reports for Perth County municipal system revealed that only one had backflow preventers installed at each lateral connection to major industries. The City of Stratford was encouraged to continue its efforts to ensure installation of backflow prevention devices at all major and high-risk industries.

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Questions to Ponder

1. Would your system respond any differently (better or worse) to these circumstances?

2. Does your water system Emergency Response Plan address all of the actions that were required for dealing with this case? In particular, do you recognize institutional users such as hospitals and long-term care facilities that will be particularly adversely affected by a loss of water supply?

3. Is your relationship with public health authorities capable of dealing rationally and effectively with such an episode involving a potentially toxic risk?

4. Do you have networking arrangements in place that would allow you to call for assistance from other water utilities on an emergency basis?

5. Do you understand what elements of your distribution system have the potential to be impacted in this manner by such a cross-connection episode?

6. Do you have a functional cross-connection control program?

7. Do you have a bylaw that makes illegal such cross-connections without functional backflow prevention?

Lessons

1. Adverse conditions can develop extremely rapidly, and you will need to be able to respond accordingly, likely with major commitments of time and energy from key staff.

2. When a serious incident is developing, you need to be able to engage your leadership as well as staff to be ready for extraordinary commitments of time and energy to keep up with and eventually gain control of circumstances.

3. Effective leadership is vital to manage an episode like this to avoid serious harm, unnecessary efforts and public loss of confidence.

4. An accurate checklist of all the regulatory and customer service obligations for your system must be accessible to effectively respond to a negative incident.

5. Public health agencies will likely not be very familiar with all of the water quality implications of major incidents like this, partly because water quality issues that cause public health problems are rare compared with other ongoing public health issues like substance abuse, immunization, communicable disease control, obesity and health, social issue health determinants, and so on.

6. Effective bylaw enforcement and inspection programs are necessary to pick up such dangerous cross-connections before they can cause harm.
“I believe this book should become a mandatory read for any operator seeking a Level I certification. Reading this book will certainly bring about some changes in the water treatment plant I manage. Thank you for the insights you and your colleagues have provided.”

Garth Carl, Operator

“There is tremendous knowledge and insight in this book. From an operator’s perspective it’s like watching a train wreck and being reminded that you are riding the same train. You have created a valuable operational tool.”

Jamie Giberson, Operator

“This book is a must-read, not only for drinking water operators, but the entire drinking water industry. Comprehension and application of the practical information contained in this book by operational personnel, regulators, equipment manufacturers, decision-makers, consultants and academia will undoubtedly save lives in the future.”

Brian Jobb, Manager