THE WALKERTON INQUIRY

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ONTARIO WATER SUPPLIERS: TWO EXPERTS' ASSESSMENTS

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Abstract

This paper is the product of the tour by two experts of 27 Ontario water suppliers (in 19 communities) in June–August 2001. Dr. J. Edward Singley focused on the facilities, engineering, processes and staff training; Edwin E. Geldreich examined watershed and distribution-system management, bacteriological conditions and sampling, and treatment methods.

The sites, selected by Commission staff, included a broad range of plants and management that varied in types of ownership, operating authorities, water supply sources, populations served, and plant sophistication. However, the authors were asked not to include issues normally addressed by government inspectors or in engineers' reports required by the Ontario Drinking Water Protection Regulation.

Each visit consisted of a tour and a detailed interview with plant personnel.

About the Authors

Dr. J. Edward Singley, the author of section 2, has worked as a process and operations consultant in the drinking water industry for over four decades. He received the Abel Wolman Award of Excellence from the American Water Works Association (AWWA) and is a member of the Water Industry Hall of Fame. He served as president of AWWA in 1991–1992. His experience includes 38 years of university teaching, the last 25 at the University of Florida's Department of Environmental Engineering Sciences.

Edwin E. Geldreich, the author of section 3, is a research microbiologist whose experience includes the pioneering development of the membrane filter technique for use in sanitary microbiology, the origination of the fecal coliform concept, and the writing of over 125 articles in peer-reviewed publications. He is also the recipient of the Abel Wolman Award of Excellence. His experience includes 46 years of water research in the U.S. Public Health Service and work as senior microbiologist with the U.S. Environmental Protection Agency.

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1 Introduction

1.1 Assignment

The Commission, wanting a second view on the state of Ontario's systems, asked us – two senior experts with no past, present, or likely future connection with water engineering or policy in Ontario – to visit 27 water supply operations in the summer of 2001. A wide variety of smaller systems were selected for a site inspection and in-depth discussion with the operators. No clear and present dangers were observed, though a number of observations were passed along to the operators in the course of the visits.

The Commission is grateful to the municipal and Band Council authorities who facilitated these visits and whose frankness made the exercise so worthwhile. Wayne Scott, formerly of Ontario's Ministry of the Environment, took care of all logistics.

1.2 Approach

In organizing the study with Commission staff, we agreed to the following points:

- Two one-week visits would be made to a variety of water supply sites in Ontario. The sites, selected by the Commission staff, would include a broad spectrum of types of plants and of management.

- We were to report (to the Commissioner) our opinions, impressions, and recommendations for any changes in current and future operation that would strengthen the province's water supply program.

- We were not to include, in the process, any of the materials or issues normally addressed in the inspection programs conducted by the Ministry of the Environment to ensure legal compliance. Nor were we to include issues conventionally addressed in the engineers' reports required by Ontario Drinking Water Protection Regulation (O.reg 459/00).

This paper has been prepared for discussion purposes only and does not represent the findings or recommendations of the Commissioner.

We agreed to focus on the following aspects:

- watershed management;
- source water;
- operational details of the treatment processes;
- operational details of the distribution system and its management, including sampling technique and analytical control, corrosion control, flushing program details, backflow and cross-connection prevention and control policies, and leaks and repair of leaks;
- bacteriological and biofilm conditions;
- bacteriological sampling details, including submission of samples, laboratory coordination and availability, utilization of laboratory results, response to adverse results; and
- management of the works, including rates, use of metering, involvement of staff in waterworks professional organizations, training programs for operational staff, and relations with other government agencies.

We were supplied with the following information:

- a recent engineering report,
- any other water quality or consumer confidence reports available for the utilities,
- a description of the facility, and
- any other relevant file information.

1.3 Activities

We visited 19 communities with 27 different waterworks that covered a broad spectrum of sites, including types of ownership, operating authorities, water supply sources, and size of population served.

1.3.1 Period of Tour

June–August 2001.

1.3.2 Ownership of Plants Visited

- 1 – Ontario government
- 3 – First Nations
- 2 – regional government
- 20 – municipal government
- 1 – improvement district

1.3.3 Operating Authority – Plant and/or Distribution System

- 1 plant – Ontario government
- 3 plants and distribution systems – First Nations
- 2 plants – regional government
- 15 plants and 23 distribution systems – municipal government
- 1 plant and distribution system – improvement district
- 5 plants – Ontario Clean Water Agency
- 1 plant – private contractor

1.3.4 Water Supply Source

- 9 – surface water (lakes and rivers)
- 18 – groundwater

1.3.5 Size – Population Served

- 6 – 10,001 to 70,000
- 11 – 1,000 to 10,000
- 10 – fewer than 1,000

1.3.6 Sophistication of Facilities

These ranged from state-of-the-art to the minimum required by Ontario regulations.

1.3.7 Procedure

At each utility, we surveyed the physical aspects of the operation. Following this, we did a detailed interview with the plant personnel, utilizing the appended survey form (see Appendix A–1) to guide the discussion. In several of the cases, political and/or management personnel joined the group and participated in the interview.

To begin each interview, we set out the following points with the participants:

- the purpose and format of the interview;
- our qualifications;
- how our activities fit the overall Inquiry process;
- that no names of individuals nor waterworks would be identified;
- that the survey form (Appendix) was neither part of an inspection nor a plant evaluation, but merely a means to help us be sure we were covering the important issues;
- that we would advise them (during the interview) of any matter we felt deviated from good operation practice; and
- that the draft report would be posted on the Inquiry's Web site.

1.4 General Observations

In the course of our visits, a number of general factors became apparent:

- All of the interviewees were forthright and interested in sharing their knowledge, experiences (including any mistakes), and opinions.

- Many of the interviewees, particularly those from small utilities with several wells, were deeply concerned about the high cost of analyses for many potential contaminants that were unlikely to be present in their supplies – or had been shown to be absent.

- In many instances, we were pleasantly surprised by the workers' exceptional attitude, innovation, and outstanding performance.

- The introduction of new standards or historical performance problems had stimulated the upgrading or replacement of existing treatment plants.

- Smaller utilities often rely on one person to handle all aspects of the drinking water supply – with no backup staff with training or experience for relief.

- There was a lack of understanding of the availability of training programs or they were too far away to be utilized. This was particularly apparent for the smaller and more-isolated utilities.

- Several of the interviewees expressed concern about the public image of the analytical results obtained from a utility-selected private laboratory rather than from a provincial laboratory.

2 Engineering, Process, and Training Considerations

2.1 Operations

The processing sophistication of plants varied from simple chlorine disinfection to advanced technologies; however, the constant throughout the province was the dedication of the operators, who were very interested in and committed to meeting the regulations. Many of the simplest plants, although not properly designed to meet the treatment challenges, were performing to their utmost, due to the efforts of the operators. The more advanced plants were generally much newer – and well operated and maintained. I was concerned that some utilities were planning new or larger plants without due consideration being given to more modern processes such as membranes and ultraviolet (UV) disinfection. This can only be changed by increased exposure to the newer techniques, through training courses and seminars – and improving communication with plant designers.

Generally, the surface water treatment plants were using alum as the primary coagulant, without any use of the iron salts. Using these salts may offer significant advantages, particularly in the colder waters present over a part of the year in Ontario. I was pleased to note the use of organic polymers in a number of plants.

There was a strong tendency to use prepackaged treatment plants for small utilities. This may be a function of economic necessity, but in at least one utility, the coagulation/settling portion of the plant was being bypassed because of the difficulty in meeting the turbidity regulations. (The turbidity added by the coagulant was not removed in the settling/filtration step from a raw water that met the regulations without the additional treatment.) In at least one other case, the unit was very inefficient and needs to be replaced. Increased monitoring of the effluent and of operating efficiency should accompany the continued use of these units.

The understanding of the plant's chemistry and processes was frequently limited to the basics. Nor was there a strong understanding of the basis of the regulations. This leads to confusion as to the goals to be achieved or exceeded. The objective should always be to do a better job than required because of the importance to human health. The regulations should be understood as *minimum* requirements. This factor needs to be emphasized and strengthened. The ultimate protection of public health lies in the hands of the plant operator. The more knowledgeable the operator, the greater the public's protection.

2.2 Training

There is a general lack of knowledge about the availability of training courses or product seminars. Distance is another problem, particularly for small utilities that do not have the training funds available for travel support. If human health is to be protected, educational activities need to be provided and accessible, perhaps mandated, with strong support through organization, supervision, and funding. A program needs to be developed that involves the Ministry of the Environment and possibly the Ministry of Health in either the design or co-sponsorship of training activities.

The first step in a certification process should include basic math, chemistry, and biology, plus a knowledge of regulations, disinfection, and various treatment processes. Advanced certification could result from specialized knowledge of the drinking water field. Many of these subjects are available through videotapes, computer-based training, or other self-taught means – and many courses are available through the Canadian Water Works Association and the American Water Works Association.

The Ontario Clean Water Agency offers internal training courses. These should be made available to other utilities in the area, perhaps by co-sponsorship with the Ministry of the Environment. The ministry needs to take a proactive role in the training process because of its critical importance in the production of safe drinking water. One approach that has been used very successfully in Florida (and elsewhere) is the provision of "circuit riders" – experienced operators who visit smaller plants and conduct one-on-one training, focusing on the particular problems encountered in that plant. These "circuit riders" are employed by the regulatory agency.

The most important aspect of training is to ensure that the operator training and certification system measures success by ensuring that *all operators* are involved in the process. Additionally, the ministry must be confident that the operators have the basic knowledge needed to operate their plants. Next, the operators must have the opportunity to develop additional knowledge and skills – along with a desire to produce the best water quality possible. Strong management support and the establishment of an environment to foster that objective can best accomplish this last goal.

If protecting public health is the primary objective of training and certification of operators, the system *fails* if it measures only the number of courses presented and the number of participants. Such a scale doesn't account for reluctant or lazy students, or impoverished or miserly operating authorities. And new employees can be overlooked or claim that appropriate training was not available. Incidentally, First Nations' operators should be involved in all training programs.

Some staff noted that advice or guidance from regulatory agencies was limited because of frequent personnel changes – or the replacement representative was unable to help. When the same representative was present for an extended period of time, knowledgeable help almost always resulted.

2.3 Recommendations

- The monitoring requirement for the extensive organic contaminant list should be reduced for those utilities that use groundwater that has had no evidence of the presence of those compounds in the prior year. The costs of full-scale monitoring to small utilities, particularly those having more than one well, are hefty. These funds could be used more productively to fund many, more-needed improvements.

- The ministry should establish a system for analyzing occasional samples to assure the public of the reliability of the water supply.

- The Ministry of the Environment should adopt a proactive role in the training and certification of operators. It should empanel a group of qualified persons to evaluate the present situation, design future programs, and monitor results.

For the first level of a certification program, the minimum requirements should include the following:

- basic mathematics, chemistry, microbiology, and hydraulics. (These four could be obtained by self-study, using one of the available study guides from AWWA, California, etc.);

- a knowledge of provincial regulations;

- some information on the chemical aspects of treatment processes. (For this, students may need instruction from an experienced operator in their plant or in another plant.)

Circuit riders (mentioned above) who have specific knowledge or skills could travel to smaller or more isolated plants.

Ministry or educational system employees or senior operators should monitor the tests.

Advanced certification should be based on additional use of educational opportunities – short school sessions, seminars, community college courses, self-study programs – *but only* when those courses include testing of satisfactory comprehension of the material.

The requirement for hands-on experience should be one year maximum, so that more educationally qualified people would apply and be more rapidly advanced. The increasing complexity of the treatment processes and the applicable regulations requires better-educated operators. Making opportunities available is the only way of attracting such candidates.

A well-organized operators' association can facilitate training. In some American states, such an association has "sections" that cover the state. Each of these sections conducts "short schools" at various training levels. Some use continuing education units (CEUs) to certify attendance.

Circuit riders should be employed to establish contacts with small utilities and provide one-on-one training.

These recommendations are based only on my observations and interviews – not on any review or knowledge of the current status of training or certification in Ontario.

3 A Safe Water Strategy: Microbiological Considerations

3.1 Basic Public Health Concerns in Water Supply Management

Pristine water resources (aquifers and surface waters) worldwide are becoming scarce as a consequence of long-term abuses, which have introduced fecal wastes and industrial chemicals into source waters. In the process, public water supplies, in many locations, have progressively deteriorated and placed a greater burden on water utilities to upgrade treatment to protect public health.

While soil barrier protection of aquifer resources still exists, there are many instances where this barrier is becoming less effective because of landfill operations, injection of industrial waste into the ground, applications of agricultural chemicals over farm fields, and the poor treatment of domestic wastes by ineffective septic tank systems. Streams and lakes are more vulnerable to pollution loading because there is no physical barrier to block rapid transfer of wastes to these receiving waters. In fact, the natural capacity of streams and lakes to recover from increasing inputs of pollution has been significantly reduced – some streams may never recover from the overload of municipal pollutants introduced from expanding metropolitan areas, industrial release of complex organic wastes, and agricultural operations involving stormwater runoff from animal feedlots and poorly contoured fields. As a consequence, watershed and aquifer protection are vital and should be strengthened to stabilize any further deterioration of source water quality.

In the past, minimal treatment would ensure a safe water supply. Today, few groundwater systems are safe enough to be approved for public water supply without some specified treatment. While simple filtration and chlorination of surface waters once provided sufficient barriers to microbial contamination, increasing problems with a variety of discharges and agricultural activities over the drainage basin have produced major fluctuations in raw source water quality. The net result has been an increasing burden on conventional water treatment processes. Even with the expansion of water treatment schemes into more complex and costly processes, there still exists the risk that water treatment barriers will be breached by some overwhelming pollution event. Therefore, the nature of the source water should be a priority consideration in the design of the water treatment system. Regulatory oversight should include input to and review of watershed activities – and veto power on any proposed discharge permits that might create poorly controlled effluents in the upstream segments of the water resource.

The final barrier for protecting water quality is the distribution system. Once processed drinking water leaves the treatment plant, it should move quickly through the distribution system to prevent quality deterioration. Stagnation of the water supply encourages biofilm development, accelerated corrosion, enhanced accumulation of heavy metals in sediments, and taste and odour problems. A minimum and specified (20 [psi]) water pressure is critical and should be present at all times, along with a measurable disinfectant residual, to provide protection from cross-connections that may suddenly develop.

An excellent water supply cannot be sustained without attention to storage protection, and to delivery to the consumer through a clean pipe network. Unfortunately, the service life of tanks and pipes is finite, and water quality will not remain unaltered during prolonged storage and retention in the pipe environment. An effective, system-wide flushing program and active corrosion-abatement measures are essential in combating the adverse effects of long-time retention of water supply in the distribution system.

After a century of investigations into water-borne outbreaks worldwide, most epidemiologists conclude that the "sudden emergence" of new pathogenic agents is, in reality, a result of breakthroughs in the recognition and detection of additional agents never before associated with water supply. Most summary reports on water-borne outbreaks have repeatedly shown that only half of the outbreaks had identified agents associated with the contaminated water, while the other events were caused by "unidentified agents." The reasons for this failure often lie with field investigations that did not start within hours of the first case exposures, the transient nature of contamination breakthroughs into the system that go undetected by a poor monitoring program, and unsatisfactory selection of special testing procedures used to isolate the agent from water and consumers.

Advances in science have provided a variety of specialized laboratory techniques to detect more of the unidentified agents. Unfortunately, these laboratory tools are not frequently found in the average monitoring laboratory, where the focus may be solely on coliform analysis. Rare is the discovery of a new pathogen that has evolved suddenly from non-pathogenic predecessors. Perhaps *E. coli* O157:H7 could be cited as an exception, as it may have mutated from a non-pathogenic intestinal bacterial species. Other organisms of growing concern in the temperate world include *Salmonella typhimurium, Shigella, Heliobacter pylori*, *Mycobacterium avium* complex, caliciviruses, *Cryptosporidium*, *Cyclospora cayetanensis*, *Toxoplasma gondii*, and two Microsporidia (*Enterocytozoon* and *Septata*). Additional microbial agents will undoubtedly be added to the list, as the science of detection and associations with water-borne outbreaks are discovered. *Giardia* is a good example. Prior to the 1950s, the medical world considered this protozoan to be a non-pathogenic organism that was a normal part of intestinal flora for approximately 30% of all people. Now we know that this was a mistake in judgment.

3.2 Review of Ontario Public Water Systems

3.2.1 Watershed Management

Many systems visited were involved in watershed management through membership on various committees concerned with the surrounding watershed activities. However, there was little evidence that water supply had a higher priority than agricultural development or community growth. For example, two waterworks on the Grand River reported the greatest fluctuations in water quality and the potential menace from spills upstream. Turbidity and coliform fluctuations in this river are driven by agricultural and urban area erosion during stormwater runoffs. In other places on the river, the problem is acid mine drainage that results in periodic fish kills.

In northern Ontario, some watersheds are controlled by First Nations' communities, while others have no organized watershed management because the land is said to be "vacant." In contrast, one high-quality lake resource is protected for source water use through city ownership and restrictive-use laws. While most of these watersheds are remote from high population densities, they are exposed to agriculture, mining, and logging activities. One community we visited had a soil contamination problem around the village and water plant site from fuel oil leakage that went undetected for months. On the positive side, another community blocked the proposed use of an abandoned mine as a repository for Toronto's garbage.

3.2.2 Raw Water Quality

The concern for *Cryptosporidium* in surface water sources has driven some utilities to abandon their traditional high-quality surface water sources and go to groundwater, largely because it was more cost-effective than building filtration plants. One waterworks is concerned that its lake source may not be large enough to provide for the community's future expansion. Other utilities have other water quality problems: high total organic carbon (TOC), high turbidity, high chlorine demand, elevated manganese and iron, or anaerobic conditions during the winter or lake destratification.

The microbial quality of groundwater, in all visited sites, is generally excellent, but one utility reported coliform occurrences when the weather is hot, possibly due to high water demand and inadequate disinfection contact time. Another utility is concerned that the groundwater resource is being pumped at capacity at their three wells – and that deeper wells may be needed to reach the shrinking aquifer.

3.2.3 Treatment

We encountered many different treatment sequences: simple chlorination of groundwater, prepackaged plants with ion exchange (to remove taste and odours), conventional treatment (PAC/coagulation, GAC/filtration,[1] settling, disinfection), advanced schemes using conventional treatment plus UV to degrade organics, and state-of-the-art ultrafiltration system using hollow fibre membranes. Several of the systems are automated and only operate 8 to 12 hours per day. Start-up time for one system was eight minutes, during which time the water was run to waste before treated water was allowed into the distribution system's storage tank.

Disinfection contact time was inadequate in several systems. One utility planned to correct this by constructing a baffle to slow the flow of water in the contact chamber; in another utility, the anticipated remedy was repositioning chlorine

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[1] PAC is powdered activated carbon; GAC is granular activated carbon.

injection to the wellhead plus blending the two wells at this point. This latter utility was desperately searching for financial support to make this change in their groundwater treatment scheme. Another utility had a problem because the interval separating the injections of chlorine and fluoride was insufficient. This situation resulted in the formation of a sludge because the mixing with groundwater was not complete.

Application of chlorine gas to disinfect water does require care and should always meet strict safety protocols. One utility, using chlorine gas, had a near-fatal event some years ago due to lack of proper safety equipment during a gas leak. While chlorine gas can be used successfully, provided all safety issues are satisfied, there is less risk in using a 12% solution of sodium hypochlorite. This practice is highly recommended.

Chemical quality achieved from process to finished water was the primary focus at one large water supplier. There was little interest in acquiring any further bacteriological information within the treatment process basins beyond the required daily coliform test of the raw and finished water. Their argument was that the lake source was always uniform and easy to treat for coliform bacteria – and heterotrophic bacterial colonization within treatment processes was not considered an issue.

3.2.4 Distribution System Maintenance

While most systems follow a system-wide flushing program every spring and fall, several small waterworks only occasionally flush sections of the pipe network. Several utilities only take action after there is evidence of dirty water (turbidity), taste, and odour complaints, high "background" counts (200 or more background colonies on coliform test cultures), line breaks, or loss of disinfectant residual. One utility reported trouble establishing chlorine residuals in dead ends, even after flushing the 366-metre line all afternoon. Bacteriological samples taken in the pipe section were also found, occasionally, to have coliform bacteria. Utilities often differed in their policy to flush static water zones (occasionally, every Wednesday, or every other week, depending on complaints or loss of chlorine residuals).

Further inquiry revealed that in those utilities that do not flush the entire pipe network, there are problems with some fire hydrants that do not operate because of soil heaving in the winter, and street valves (on the mains) that are frozen and need repair. These same systems reported occasional biofilm problems and sediment buildup in the pipelines. On the positive side, several systems have made an effort to loop their lines to avoid the problems with dead-end sections. Another utility made an effort to clean the water supply tank of sediment every year.

3.2.5 Interpreting Bacterial Significance in Drinking Water

Investigation into the use of data from bacteriological reports revealed some inconsistencies in the interpretation of information on the heterotrophic bacterial population in water supply. Many systems follow the Canadian guidelines concerning the general population of bacteria observed on the membrane filter procedure for total coliform detection. In essence, if there are more than 200 non-coliform bacteria in the culture of a water sample, then this becomes a signal to flush that section of lines. This is a very poor approach to measuring the magnitude of heterotrophic bacteria occurring in a drinking water sample. Several utilities do request a heterotrophic plate count and use a value of 700 organisms per mL as a signal to flush the lines.

In discussions with utility personnel, it appears that some waterworks receive their total-coliform reports in a format that notes only presence or absence from a laboratory that may be using the membrane filter test. This is acceptable by Ontario regulations, but the opportunity is lost in providing the plant operator with some additional information about the magnitude of the problem from the same test material.

3.2.6 Monitoring for Safe Water Quality

Many utilities select Monday or Tuesday to collect all required samples for the week. There is often no further monitoring for microbial contamination until the following week. Reasons given for this fixed approach are said to be dictated by the time required to get a test completed and results released (by the laboratory to the proper water authorities) within the work week. The response to any coliform-positive samples is an automatic re-sampling of the site, plus additional samples collected above and below the original site. It is not clear that the standard reaction plan for all utilities included a flushing of the area to remove pipe sediments and restore a chlorine residual at the location in question.

Only one utility reported a repeat coliform-positive sample in the system. This is to be expected for several reasons: the transient nature of most breakdowns in the treatment barrier, the brief nature of many back-siphonage events, and the elapsed time involved between first sampling and the time re-sampling is started.

One utility does collect samples on the distribution system four days per week and is proposing to eventually monitor the system seven days a week. Another waterworks had developed a pool of 35 sampling sites from which a different site is included each week. Many of the small city utilities have a fixed pattern of sampling site locations, such as one sample taken from the raw source, one from the finished water, and five samples taken from fixed locations (mostly public buildings) on the distribution system.

One encouraging observation: several utilities perform a simple Coli Alert test of treated water supply leaving the plant on Saturdays and Sundays. While these results are not generated by a certified laboratory, the data do provide the operator with some indication that the water quality being released at the plant is meeting the limits for total coliform and *E. coli*. All water utilities should be encouraged to take this approach as verification that treatment barriers are functioning over the weekend period. Unfortunately, one utility discontinued their operator tests on the weekends, since they are not considered part of the official information base.

Prompt analysis of bacteriological samples ensures a greater opportunity to recover any stressed coliforms in the water sample. Most of the sample collections reach the laboratory within 24 hours. However, transport time is a problem in some locations due to the carrier used. It takes two days for samples collected at one utility to reach the laboratory because the package is first sent to a hub location and then transshipped on to its destination.

3.2.7 Conservation

Many small systems do not meter the amount of water used by the consumer, electing instead to charge a flat rate per month. In several instances, water is delivered free because of the low incomes within the small community. It is also within these small communities that concern was expressed about the need for water conservation because of the limited yield of the well or the fact that a major fire that had taken over four hours to control would completely drain the water supply.

3.2.8 Emergency Preparedness

Many systems do not have emergency plans in case of catastrophic treatment or distribution system failure. However, one medium-sized utility had recognized its need for emergency preparedness and had documented their plans.

3.2.9 Access to Information

Management in several waterworks reported that recent provincial requirements to make available complete documentation on chemical and microbiological data for each quarter are a cost burden estimated at $4,000 to $10,000 per quarter, depending on the size of the utility. While the cost may be less for smaller utilities, it represents a significant part of their operating budgets. Little public interest has been shown in these voluminous reports.

3.2.10 Relationships with Other Government Entities

Inquiries into relationships with the local health unit of the Ministry of Health and with the Ministry of the Environment elicited a mixed reaction from management. Apparently, changes in direction on the part of these two ministries have had an effect: while some utilities still have a good rapport with their government overseers, others report that communication and in-depth assistance is not like it was in past years. In some cases, new employees at the Ministry of the Environment are inexperienced in water supply problems, citing only references to regulations – and providing no significant assistance. Another part of the problem appears to be a shift in program direction, together with loss of funding and experienced staff.

3.2.11 Review of Water Supply Guidelines and Regulations

Several utilities complained about the scattering of regulations through various legal publications, which should be consolidated into one unified document.

Management in one utility stated the turbidity regulation should be more specific for those groundwaters that are under the influence of surface water. Regulations for small water systems supplying water to at least six service connections that require specific chemical tests at a specified frequency may not reflect a realistic cost-to-calculated-health-risk potential. Frequent concerns were expressed about the layering of so many regulations on small groundwater suppliers: this may put them out of business because only limited resources are available to do all the required testing. If so, small clusters of homes on these public systems would be forced to drill their own wells to acquire water of unknown quality.

3.3 Overview and Recommendations

Continued strings of negative coliform results over several years has given some utilities a false sense of security. In reality, it is normal for a water supply treatment and distribution system to occasionally detect coliform occurrences in a few samples each year. Several systems in this survey reported no coliform occurrences over the past three to five years. This unusual record may be due to two factors: always collecting samples from the distribution system on a specific day of the week, and maintaining a fixed pattern of sampling sites selected from the distribution system. Water utilities, particularly surface water systems and those plants that are processing groundwater under the influence of surface water, need to be more active in their dedicated vigilance for irregular contamination breakthroughs in treatment and at intermittent cross-connections in the distribution system.

As a consequence of the recent reports of water-borne outbreaks in the province (and other places in Canada) there has been an erosion of public confidence, some of which is unjustified. In other situations, the water supply provider needs to be more aggressive in testing the extent of treatment barrier effectiveness and distribution system integrity to avoid the risk of a future water-borne outbreak. The following observations from this field assignment reveal significant concerns that need to be addressed by Ontario water supply experts as they formulate new directions toward a uniform, safe, public water supply for all citizens throughout the province.

3.3.1 Watershed Management

An independent agency or commission is needed:

- to perform a comprehensive watershed inventory of all existing and potential land-use activities that impact on water quality;
- to monitor for spill occurrences, and to alert the water suppliers with intakes downstream;
- to find and eliminate waste-spill problems; and
- to penalize violators discharging unacceptable effluents.

At this time, no precise information is known about all of the contributors of waste discharges nor the location of outfalls. In the Grand River and other watersheds, there is strong resistance to any controls or regulations that have an adverse impact on agricultural operations, which are given prime consideration over water supply source protection.

Major attention should be given to the development of an early warning monitoring system for spills on the Grand River (or other river basins where warranted), which one water authority, during our investigations, called "perhaps the most polluted river in Canada." Such a monitoring service, operated by an independent commission, would ensure that all spills are identified and promptly reported to downstream water utilities that use this resource as their raw water supply. For example, following a major storm event over the Grand River watershed, turbidity fluctuates, widely, from 16 NTU (nephelometric turbidity unit) to over 400 NTU in a few hours – and total coliform densities often range from 12,000 to 14,000 per 100 ml. There is some recognition of the spill problem in this river basin – and a phone alert to downstream water utilities often occurs, but it is not always prompt and does not cover clandestine spills by industries and farmers.

Strategic locations for monitoring sites along the drainage basin, selection of parameters to be measured, and the development of remote sensors could alert operators to toxic waste discharges, high chlorine demand, drastic shifts in pH, rising levels of turbidity, and loss of dissolved oxygen. Some of these conditions are associated with an increase in bacterial nutrients in domestic wastes and paper-mill effluents, the loss of stream self-purification, plus the accelerated microbial degradation within the river. The concern is that such deteriorations in water quality may overwhelm the treatment barriers engineered in processing surface water and lead to a breakdown in the production of a safe water supply.

If given advance warning, some water plants have the option of shutting off the intake of raw water during the passage of a spill downriver; however, there are limitations imposed on length of time such closures are possible during a spill passage. One utility reported that they can shut down the intake for three days, if necessary, to permit passage of a pollution plume. Other utilities appear to have less storage time, either in the raw water basins or in finished water storage in the distribution system.

3.3.2 Raw Water Quality

Protecting raw water from further degradation must be an essential part of protecting the environment and an irreplaceable first barrier in water supply treatment. There does not appear to be any effort to link changes to raw water quality with the impacts from watershed activities that are causing degradation of the natural resource. While all waterworks do monitor their raw water quality once per week for total and fecal coliforms, little use appears to be made of the opportunity to do a seasonal examination for pathogen occurrence using *Salmonella*, enterovirus, and *Cryptosporidium* as indicators of risk in surface water sources. These occasional pathogen screening tests should be done by all waterworks that serve a population over 10,000 and that use a surface water source that contains more than 100 coliforms per 100 ml. Seasonal peaks in pathogen occurrence should trigger treatment adjustments to ensure there is adequate barrier protection in water supply processing. Smaller systems were found to use groundwater, which generally provides a barrier protection from surface contamination, and they would not be included in this recommendation because of laboratory costs to do pathogen testing.

3.3.3 Treatment Considerations

Significant raw water quality changes can occur in surface waters and do alter the effectiveness of various treatment processes serving as microbial barriers.

For this reason, an active in-plant process monitoring plan should be in place to intensify the response whenever predetermined levels of degradation are reached in raw water quality. The urgency is to be alert for possible microbial breakthroughs in treatment process water.

Within the treatment sequence, there should also be an ongoing characterization of process water for

- significant amplification of heterotrophic bacteria;
- micro-organism passage through unstable filter beds;
- recycling quality of residual backwash water;
- short-circuiting in treatment processes through faulty common-wall compartments,
- biofilm colonization on agitators, compartment walls, and interconnecting process flumes; and
- inadequate contact time in disinfection basins.

While emphasis in treatment effectiveness is on reduction of coliform bacteria and potential intestinal bacterial pathogens, many other kinds of bacteria are present in process water. These organisms can signal the need to clean up treatment basins so that such organisms (which include opportunistic bacterial pathogens) may not emerge in the water supply as a health threat to children, individuals with AIDS, patients on chemotherapy, and senior citizens with weakened immune systems. These "housekeeping" measures should be part of an aggressive activity in every water treatment plant. Such was the philosophy at one water utility that has customized treatment and monitoring of wells in various parts of the city; however, little evidence of a similar approach was seen at other plants.

Water utilities that do not utilize a continuous processing of source waters should always have concerns that their treatment system will not be stabilized immediately. This is because start-and-stop filter runs may be unstable for a short time and permit the passage of contaminants into the water supply unless sufficient time is provided for filtering the process water to waste before permitting the product water into the next treatment stage. Unstable filter beds are a particular concern because of the threat of microbial breakthroughs into the drinking water supply. Such automated systems need to employ a different monitoring strategy based on continuous measuring of filter turbidity whenever the source-water turbidity exceeds 100 NTU. The concern is that any pathogens embedded in particles will pass through the disinfection contact basin without being inactivated. One utility recognizes this concern and uses an in-plant Coli Alert test to monitor the impact of system start-ups every day, when source water has high turbidity. Unfortunately, the test results take time (18 or more hours) to process, but they do provide a historical record of treatment performance as a microbial barrier.

3.3.4 Distribution System Maintenance

A continuing program to systematically flush the distribution pipe network twice a year (spring and autumn) and inspect and clean all water storage tanks and standpipes (every three years) is essential. Managers of distribution systems need a proactive program to suppress biofilms in sediments – the source of excessive heterotrophic bacteria, including some opportunistic organisms that could be a health risk. Focusing attention on dead ends and static zones in the pipe network is essential. Several systems have recognized this problem and are in the process of looping many of the dead-end lines to achieve a continuous flow of water. The most important consideration in any water distribution is to keep the water moving by minimizing the creation of dead-end pipe sections (which happen when growth projections are unrealized). This condition often results in retention times of over a week – in both the pipelines and water supply storage tanks.

Information on water supply retention time in the distribution network is not available for most systems. Those who estimated retention times said that these values were “in the ballpark” and not based on a careful study of water flow. Such information needs to be developed and used in the location of slow-flow areas and for scheduling additional flushing frequency in these portions of the pipe network. Several waterworks did have an active program to loop dead-end sections of the pipe network for better circulation of water, thereby increasing free chlorine residuals throughout the system, reducing taste and odour problems, and suppressing microbial colonization (biofilm) opportunities.

An active cross-connection program is another important way to protect the integrity of the distribution pipe network from potential incursions of fecal contamination into the water supply. For many of the utilities visited, this activity is the responsibility of the town building division, which reviews all new building and remodelling plans. Several utilities reported good communication links with this local government authority. No utilities or building divisions had a plan to schedule revisits to those sites that are always potential threats (industrial operations, car-wash businesses, lawn irrigation schemes, interconnecting cisterns, hospitals, clinics, funeral homes, etc.). In several instances, the cross-connection control program is delegated to the water utility, which may not yet have started any activity to assess the issue. One utility reported knowledge of several cisterns with interconnections to the public water system. However, the utility no longer has enforcement powers to ban such operations because of an adverse legal decision that favoured individual rights in such instances.

3.3.5 Interpreting Bacterial Significance in Drinking Water

The established use of "background" counts of non-coliform bacteria growing on the membrane filter test medium (M-Endo) for an indication of the magnitude of the heterotrophic bacterial population is a crude measure of occurrence. Endo-type media were designed to maximize recovery of coliform bacteria and suppress other members of the heterotrophic bacterial population. Research development of these differential coliform media have shown that the suppressing agents (basic fuchsin and sodium sulfite) effectively eliminate 95% to 99% of the non-coliform population in a given test culture. Thus any limit for "background" organisms in the test portion is grossly misleading since it represents only a small fraction of the entire population. Considering that 200 "background" colonies may only represent 5% of the total population present in the test portion of a treated drinking water, it presents an action limit that is beyond acceptability. A separate test specifically developed for heterotrophic bacterial cultivation – such as the R-2A agar procedure (five days incubation at 27 °C) referenced in any recent editions of *Standard Methods for the Examination of Water and Wastewater* – should be used for this purpose.

This underestimation of the heterotrophic bacterial population obscures the existence of poor quality water in distribution lines that need to be flushed to clean out biofilm and sediment deposits. A further concern is the potential loss of coliform detection in the sample because of interference from excessive densities of other heterotrophic bacteria. One utility reported heterotrophic bacteria counts of more than 500 organisms per ml in several sites on the distribution network and no coliform bacteria present in any samples since

1996. This suggests a possible interference with coliform detection in the test from excessive "background" bacteria – or at least a pipeline that needs to be flushed to improve the microbial quality of the water supply.

Laboratory results are based on a coliform presence/absence concept, which is used to determine the 5% limit for coliform bacteria from all samples examined during a 30-day period. This is the accepted national standard for compliance. While this approach to establishing acceptable water can be done by using a qualitative test, some laboratories acquire the same information by using the quantitative MF (membrane filter) coliform test. However, they report only the presence or absence of coliforms as required in the official data release. What is lost in this test result is data on the actual density of coliforms present in the sample, which could be useful to operators. High densities of coliform bacteria may be an indication of a treatment barrier malfunction, cross-connection problem, or a biofilm development in part of the pipe network. Such information is even more useful if seen in a repeat sample. Currently, such data is not available to the operator. Laboratories that use the quantitative MF test should be encouraged to make available this additional information from their testing so that there can be an additional characterization of water quality beyond just the report of coliform presence or absence.

3.3.6 Monitoring for Water Quality

Through monitoring, utilities maintain a frequent characterization of their treatment process effectiveness and demonstrate that a safe water supply is available to the entire community at all times. While many chemical and physical characteristics can be determined in minutes or a few hours, microbial characterization of indicator bacteria is complicated by the need to grow and differentiate the indicator organisms selected. In the search for pathogens, even more time is needed to concentrate, cultivate, or identify (by microscopic examination) suspected agents among the bacteria, virus, and protozoa known to be water borne. The goal of achieving an early alert to a pathogen breakthrough is further complicated by the fact that pathogen breakthroughs may occur at any time, day or night.

Certified laboratories must not restrict the days available for sample analysis – and tests should be done periodically on weekends and holidays, to monitor the water leaving the plant. Monitoring of public water supplies should be *varied* – to cover all days and all areas of the distribution system in a random fashion. Fixed sampling sites at some public buildings is important but should not overshadow the need to spread into all areas of the distribution network. Since many of the laboratory tests are done using the quantitative membrane filter technique or the qualitative Coli Alert system (both of which are completed within 24 hours), there is no reason why monitoring should be limited to specific days. Apparently, the restricted-days policy was driven by some commercial laboratories so that other types of laboratory activities could be scheduled for the remainder of the week. This approach to meeting the mandate for testing water samples *needs to be changed* – with one or more water samples (number of samples dependent on population density served) collected from different locations on the distribution system on varying days of the week.

A fixed pattern of site selections defeats any assurance that all sections of the distribution network are tested. In the case of systems that require less than ten samples per month, one or two samples should be selected at random locations on dead-end sections and in slow-flow areas. Larger systems must also collect samples from a few random sites each week, and make sure to cover all major areas of the distribution network over the month, to verify that water quality is satisfactory throughout the entire system.

In an effort to restore public confidence in the monitoring system, all utilities that serve more than 10,000 customers should submit to a periodic examination of 10% of the required samples by an independent, certified laboratory under contract to the Ministry of the Environment, Ministry of Health, or provincial health district. This would provide a quality control check by another laboratory and an independent verification of treatment performance to meet drinking water quality standards. One utility reported that this is being done with samples collected on Thursdays. Unfortunately, the involvement of provincial laboratories of the Ministry of Health appears to be available only to small utilities that request the service. Another utility reported that laboratory results from samples collected by inspectors are often delayed. Adding to the problem, the Ministry of the Environment allegedly regulates laboratory certification for their own programs, but not for commercial laboratories that might also analyze water samples. These actions appear to be the result of budget and staff reductions at the expense of public health protection.

3.3.7 Access to Information

As an alternative to the extensive publication of waterworks data, we recommend that the public be provided with a brief annual summary of the water quality results and health-related limits for each constituent of health concern. Perhaps these summaries could be made more readable by providing tables of trends in characterizing water quality parameters – with comparisons made to established concentration limits. Such public notifications could be included with the billing statement for water service during the year. For those wanting more detailed information, the entire database could be retrieved from a utility Web site open to the public – or at municipal offices for smaller utilities.

3.3.8 Restoring Public Trust

Recent water-borne outbreaks have shaken the public's confidence in the safety of their water supplies. Restoring trust will take time and require a professional public-relations or designated "point" person (or group) to communicate with the public and press. Important objectives should include

- responding promptly to media inquiries;
- providing reporters with information on utility upgrades in treatment and resolutions to distribution problems;
- preparing press releases on health-related issues for public information; and
- becoming involved in community activities, including participation in water-study projects in school programs.

The intent of this recommendation is for the utilities to cultivate a positive image in the eyes of the community. Although some utilities are involved in these kinds of community affairs, others have made little effort.

A special annual awards program should be developed – by the Ministry of the Environment or the Ontario section of the Canadian Water Works Association – for those water utilities that are proactive and excel in some category such as development of an early warning system, treatment refinements for better water quality, action response to a water quality problem in distribution, and technical assistance to neighbouring small water systems and community projects.

3.3.9 Relationships with Other Government Entities

The shift in mission responsibilities for the Ministry of the Environment and the local health units of the Ministry of Health has resulted in a loss of technical support and expertise to water utilities in the province. This is particularly true for the small water systems, which cannot afford the cost of private consulting firms and certified laboratories.

The Ontario Ministry of the Environment needs to contract a small pool of qualified, technical experts in water supply operations to travel the province on routine visits to small waterworks (at no cost) to check up on operations and be available for assistance when emergencies occur. As another valuable resource, technical experts in the larger water utilities should be encouraged to volunteer their technical expertise – through networking with the smaller utilities – to provide assistance and emergency supplies on request. This “big brother” approach to providing assistance is being done by some waterworks, but needs other utilities to get involved and share their expertise and field experiences as a community service. Several utilities are volunteering not only their time but also have provided emergency equipment and supplies to some of the small utilities in their region. This is an example of a utility action that should be recognized with a public award for public health service.

3.3.10 Legislative Review of Water Supply Guidelines and Regulations

Over time, a collection of Ontario’s regulatory documents has appeared, featuring elements specific to different parts of the drinking water system. These separate documents need to be pulled together into a single document with their rationale included for better retrieval by utility personnel.

Regulations for small water systems specify that a list of chemical parameters be tested at a specified frequency. Some of these tests are not realistic in terms of costs versus calculated health-risk potential. Many of these chemical constituents are very stable in groundwater and need only be tested on an annual basis; others may not be pertinent to health issues or to interference with disinfection treatment and could be eliminated from the requirements. This type of regulation is a real cost burden to small water systems, particularly to waterworks supplying drinking water to fewer than 100 customers, and needs to be revised. Regulators must realize that mandates that are too demanding will drive small water systems to close and force families to resort to private wells with unknown qualities.

The report that the Ontario Clean Water Agency has more stringent requirements for drinking water than the Ministry of the Environment should be investigated by a peer panel of experts for insights into other approaches to enhanced water quality requirements. Finally, the strong lobby interest of farmers – to place agricultural interest above source protection for water supply – requires legislative controls to protect the watershed for water supply use.

3.3.11 Management Issues

The biggest issue facing many small utilities is their operating budget. Often, this is not stable and is frequently inadequate to take care of emergency repairs and maintenance. One utility reported that it needed $400,000 to make necessary improvements to disinfection treatment operations, but there was no tax base in their small community to cover the cost. For many small utilities, using a metered approach in *charging all customers* for water use might not only bring in more revenue but also create an understanding about the need for conservation where water resources are limited.

The other major issue for management of small utilities is operator training and the need for a backup operator – to substitute during vacations or illness, and when there's a need to participate in waterworks workshops and school programs. Too often the operator of a small water plant is not able to participate in essential training programs to expand his or her work skills because of lack of money and time away from duties. Rare is the opportunity to have the training-school personnel come to areas of low population density in the northern part of the province.

3.3.12 Peer Panel

Finally, now that the *Drinking Water Protection Regulation* has been in effect long enough to demonstrate its impact, it is essential that a peer panel of experts – including water authorities from the utilities and provincial agencies, plus university researchers, public health specialists, environmentalists, industry scientists, and agricultural extension agents – be given the opportunity to review the evidence and make specific recommendations about the regulations needed to avert future water-borne outbreak risks.

Appendix: Walkerton Inquiry Field Investigation of Water Utilities

System Name: ____________________

Location: ____________________

Date: ____________________

Watershed Management

- ☐ Agricultural activity
- ☐ Residential development
- ☐ Recreation uses
- ☐ Utility ownership or control on land use
- ☐ Sewage treatment (septic tanks, primary or secondary effluent)

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Raw Water Source

- ☐ Water quality
- ☐ Flash episodes, records (lake, impoundment, river)
- ☐ Groundwater (depth, soil structure, well protection)
- ☐ Blended sources
- ☐ Characterize raw water quality (coliforms, turbidity, pH, chlorine demand)
- ☐ Monitoring records available

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Water Treatment

- ☐ Filtration, filter to waste after backwash
- ☐ Untreated
- ☐ Disinfection only
- ☐ Conventional (describe treatment train)
- ☐ Continuous processing of raw water 24 hours per day
- ☐ Continuous disinfected (> 0.2 mg/L) plant
- ☐ Plant effluent turbidities < 0.5 NTU
- ☐ Plant effluent < 1 coliform per 100 mL

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Water Distribution System

☐ Corrosion tests conducted
☐ Customer complaints, recorded/maps
☐ Coliform percent occurrence
☐ Heterotrophic bacterial densities per mL
☐ Disinfectant residual detected in 95% of the monitoring sites
☐ Measurable chlorine residual at dead ends (0.5 to 1.0 mg/L free chlorine or 1.0 to 2.0 mg/L for chloramines)
☐ System flushing procedure
☐ Flushing systematically from plant outwards through each fire plug for 15 minutes
☐ Static water zones flushed frequently
☐ Pulse flushing
☐ Foam plug passage
☐ Frequency (spring and autumn)
☐ Minimize flow reversals and reduce water hammer effects
☐ Program to eliminate dead-end areas
☐ Finished water reservoir annual inspection, repair and cleaning scheduled
☐ Corrosion inhibitor additives (concentration, protocol, pH adjustment)
☐ Bimetallic glassy phosphate
☐ Zinc polyphosphate
☐ Sodium hexametaphosphate
☐ Zinc orthophosphate
☐ High molecular weight polyphosphate
☐ Pipe materials and age
☐ Program for long-term cleaning, relining, or replacement of unlined polyphosphate cast-iron pipes
☐ Pipeline breaks, percent frequency from records
☐ Water pressure and number of pressure zones
☐ Water supply retention time in distribution system
☐ Cross-connection program
☐ Monitoring sites include first customer(s), all pressure zones, dead ends
☐ Seasonal interconnection to neighbouring utility water supply
☐ Utility operates distribution system, purchased water enters system
☐ Seasonal (summerfest) distribution line
☐ Pipeline depth
☐ Configuration of pipe network
☐ Cross-connection potential (washing facilities, concession stand tap-ins, irrigation connection)

☐ Winterizing pipeline (antifreeze type, springtime flushing and testing for coliforms, HPC and disinfectant residue)
☐ Water quality monitoring (sampling sites, frequency, number per month for coliform, HPC, and disinfectant residual)

Biofilm Determination

☐ Coliform occurrence pattern (localized or random in the distribution system)
☐ Coliform record during episode (densities, percent frequency per month)
☐ Coliform speciation *(Klebsiella, Enterobacter, Aerobacter, Citrobacter, E. coli)*
☐ Chlorine residual pattern in distribution system
☐ Water temperature above 15°C
☐ Flushing impact on coliform densities
☐ Use of alternative disinfectants
☐ Evaluate conversion from free chlorine to chloramines (alert hospitals and clinics before change)
☐ Flush ends of system more often or when HPC growth exceeds 1,000 organisms per mL
☐ If chloramines are used, switch to free chlorine for several weeks each year to avoid excessive bacterial regrowth, taste and odour

Laboratory Information

☐ Utility or city health department laboratory certified by province for drinking water microbiological testing
☐ Frequency of recertification
☐ Deviation problems
☐ Sample collection practices
☐ Faucets selected are flushed for one minute or flamed
☐ Transported to the lab promptly (within ___ hours)
☐ Sample collector periodically recertified
☐ Sample bottled sterilized and QC record
☐ Laboratory involvement
☐ Samples processed same day collected
☐ MPN, MF or presence/absence technique (positive results verified)
☐ Coliform speciation method
☐ Fecal coliform or *E. coli* testing
☐ Prompt notification to water authority
☐ ____
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Action Response

☐ Repeat sampling including samples taken above and below site of positive result
☐ Booster chlorination
☐ Flushing program activated (localized or system-wide)
☐ Expanded monitoring
☐ Use R-2A agar (7 days at 28°C) for early indication of regrowth (HPC densities over 1,000 organisms per mL) and need to flush out sediments
☐ Switch from P/A test to MF for quantitation of coliform results (verify and speciate coliform colonies)
☐ Activate a search for fecal coliforms or *E. coli* in all samples until the biofilm is suppressed
☐ Province and local health departments monitor hospital and clinic admissions for illness cases possibly attributable to public water supply
☐ Issue boil water order if fecal coliform or *E. coli* are confirmed in repeat sample, loss of water pressure, or outbreak is waterborne
☐ ______________________________
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Management

☐ Clear policies, expectations
☐ Relations with MOE, MOH
☐ Technical assistance available
☐ Capital requirements met in time
☐ Customers metered
☐ Full costs recovered from customers
☐ Operators trained and qualified
☐ Accredited lab services available
☐ ______________________________
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Recommendations

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