THE WALKERTON INQUIRY

Commissioned Paper 8

PRODUCTION AND DISTRIBUTION OF DRINKING WATER

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Abstract

Through a comprehensive review of data available for drinking water treatment plants, this paper examines plant characteristics as well as the current costs and revenues associated with the water industry in Ontario. An overview of Canadian and Ontario environmental legislation, available treatment technologies, and water utility best practices is included.

Examination of current environmental legislation and operating practices provides a comparison of practices in Ontario with those elsewhere in Canada, the United States, Europe, and Australia. Operating practices of selected facilities were evaluated from responses to a comprehensive questionnaire circulated to management staff of each facility. The effects of regulation, technology, cost, and best operating practices are considered for both large- and small-scale drinking water suppliers.

Finally, the authors propose recommendations for improvements to the regulation and treatment of Ontario's drinking water.

Contents

Tables

Figures

1 Survey of Ontario Drinking Water Treatment

1.1 Introduction

There are approximately 630 drinking water treatment facilities in Ontario.[1] In 1997 these facilities served 8.9 million people, or 82% of the Ontario population.[2] The new Ontario Drinking Water Protection Regulation aims to promote uniformity in drinking water quality across the province.[3] However, quality will inevitably vary to some degree with source water quality, operating practices, and other factors.

This chapter discusses variation in source water, and in treatment plant size and mode of operation. It then relates these issues to water quality, providing insight into the challenges that exist in applying uniform drinking water quality and treatment criteria across the province. It highlights the financial and technical resources necessary to ensure that excellent drinking water is available to all Ontario residents.

1.2 Data Availability

Most of the data in this section originate from databases compiled by the Environmental Monitoring and Reporting Branch of the Ontario Ministry of the Environment. This branch is part of the Environmental Sciences and Standards Division of the ministry, whose mandate is to provide data and scientific expertise in support of ministerial policies and decisions.

Before introduction of the Drinking Water Protection Regulation in 2000, there were two main databases for drinking water: the SWIP (Sewage and Water Inspection Program) database, and the DWSP (Drinking Water Surveillance Program) database. The SWIP, started in 1989, provides ongoing snapshots of sewage and water treatment plant status, based on physical inspection reports.

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

[1] Australia, NHMRC/ARMCANZ Co-ordinating Group, 2001, *Framework for Management of Drinking Water Quality: A Preventive Strategy from Catchment to Consumer* [online], (public consultation) [cited December 2001], <www.nhmrc.gov.au/publications/synopses/eh19syn.htm>.

[2] See also Roger L. Martin, Mary Ann Archer, and Loretta Brill, 2002, *Why do People and Organizations Produce the Opposite of What They Intend?* (Toronto: Ministry of the Attorney General), Walkerton Inquiry Commissioned Paper 20, Walkerton Inquiry CD-ROM, <www.walkertoninquiry.com>.

[3] Nicholas d'Ombrain, 2002, *Machinery of Government for Safe Drinking Water in Ontario* (Toronto: Ministry of the Attorney General), Walkerton Inquiry Commissioned Paper 4, Walkerton Inquiry CD-ROM, <www.walkertoninquiry.com>.

During the 1990s plants were surveyed once every two to four years. However, since 2000 the ministry has undertaken to perform SWIP evaluations annually at all water treatment plants and once every four years at all sewage treatment plants. SWIP data describe physical and operational parameters such as chemicals and treatment processes used; they do not describe finished water quality. The data are used to measure delivery of business plan targets and to help calculate infrastructure funding needs. SWIP data are not generally disseminated to the public, but are subject to freedom of information access.[4]

The DWSP database, started in 1986, compiled data that were submitted on a voluntary basis. Initially, 22 municipalities submitted water samples to the ministry, whose staff analyzed the samples for a wide range of water quality parameters. These data, collected routinely, assisted in setting standards and assessing treatment operation. By 1999, 162 treatment facilities were participating in the program, representing 88% of the population served by municipal drinking water plants. The list of parameters monitored was extensive and included, among others, routine water quality data (pH, dissolved organic carbon, temperature, etc.), taste and odour causing compounds, radionuclides, disinfection by-products, and inorganic and organic contaminants.[5] While DWSP monitoring was voluntary, it was standard practice for the ministry to notify the operating authority and the ministry district manager whenever a health objective was exceeded. The local operating authority was then responsible for notifying the local medical officer of health.

Summary information from the DWSP database was compiled in publicly available annual reports; most are easily obtained from the ministry's Web site. Some municipalities posted their DWSP results on their own Web pages.

Since introduction of the Ontario Drinking Water Regulation, the data collection system has been modified. The regulation makes water quality monitoring and reporting mandatory for drinking water treatment facilities, with the reports submitted to the director of the Environmental Monitoring and Reporting Branch of the MOE. In practice, the ministry will enter the data into the existing DWSP and/or SWIP databases (or a modification of them). Therefore, although the structure of the databases themselves will remain largely intact, they will become more comprehensive.

[4] d'Ombrain, 2002; Pollution Probe, 2001, *The Management and Financing of Drinking Water Systems: Sustainable Asset Management,* submission to the Walkerton Inquiry (Toronto: Pollution Probe).

1.3 Water Sources

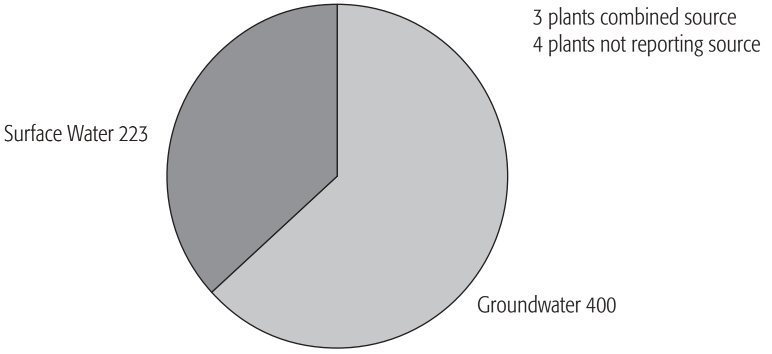
Source water quality influences drinking water quality. Raw water is taken from either ‑groundwater or surface water sources – occasionally from a combination of the two. Surface water normally requires a greater level of treatment because it is more susceptible to contamination from overland flow, municipal point discharges, or industrial waste streams. However, surface sources also provide greater volumes of water and so are preferred by larger municipalities.

According to the SWIP database, approximately two-thirds of municipal drinking water systems in Ontario (400) obtain their water from ground sources; the remaining one-third (223) use surface water (see figure 1-1).[6] Nevertheless, surface water serves almost 90% of the population (see figure 1-2), suggesting that most facilities that use groundwater serve small populations, while major urban centres rely on surface water. figure 1-3, which plots the number of plants against the size of population served, corroborates this conclusion. Almost all of the 400 waterworks that use groundwater serve fewer than 10,000 people. The major waterworks, such as those serving Toronto and Ottawa, use surface water.

An additional factor to consider when describing drinking water supply in Ontario is the impact of the Great Lakes. The Great Lakes provide water to more than one-third (251) of all drinking water treatment plants in the province. Approximately half of these are located along Lake Ontario (table 1-1). Almost three-quarters (73%) of Ontario residents served by municipal water systems drink Great Lakes water. This water is typically low in turbidity, low in microbial contamination, and low in concentration of chemicals. As a result, the treatment facilities that serve most of the population are not constrained by poor source water quality. This is not to say that Great Lakes water is pristine: one of the largest outbreaks of waterborne disease in the United States occurred in Milwaukee, where *Cryptosporidium* was shown to have contaminated Lake Michigan near the city's drinking water intake.[7] Furthermore, algae blooms in Lake Ontario have caused taste and odour problems in recent years. Nevertheless, compared with many water supplies in Canada and elsewhere, the Great Lakes offer a stable, high-quality, and abundant water supply.

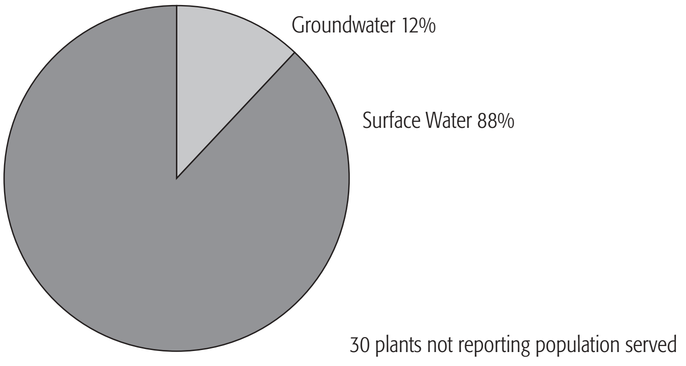
[5] See appendix 1, section A1.2.4, for a discussion of prevention strategies.

Figure 1-1 Ontario Municipal Drinking Water Treatment Plants Using Surface and Groundwater Sources, 1997



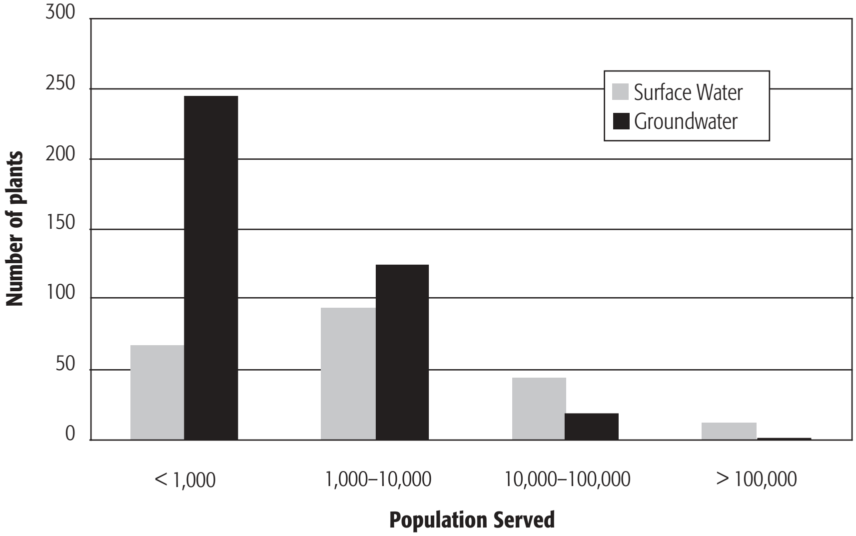
Source: Ontario, Ministry of the Environment, 2000g, *Sewage and Water Inspection Program* [database] (Toronto: MOE).

Figure 1-2 Population Served by Ontario Municipal Surface and Groundwater Systems, 1997



Source: Ontario, Ministry of the Environment, 2000g.

Figure 1-3 Type of Treatment Plants in Ontario, 1997, by Population Served



Source: Ontario, Ministry of the Environment, 2000g.

Table 1-1 Surface Water Drawn from the Great Lakes, 1997

	Number of plants	Population served	Percentage of Ontario residents on municipal systems
Lake Ontario	112	4,865,000	55
Lake Huron	83	722,000	8
Lake Erie	42	673,000	8
Lake Superior	14	215,000	2
Total:	251	6,476,000	73

Source: Ontario, Ministry of the Environment, 2000g.

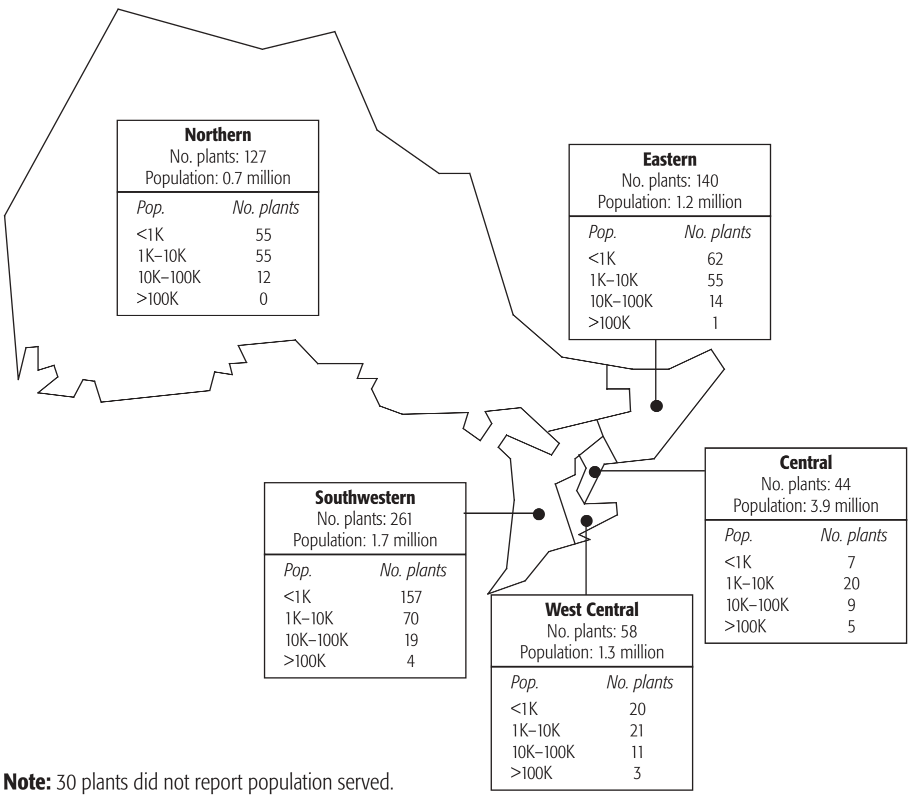
1.4 Treatment Plant Characteristics

1.4.1 Distribution of Plants in Ontario

Distribution of drinking water treatment plants in Ontario generally follows population density. The Ministry of the Environment administers five regions (see figure 1-4). Most of the 630 plants are located in the south and east of the province. The northern area, though geographically larger, has a small population and correspondingly few treatment plants. In contrast, the smaller southwestern area has the largest population and the majority of treatment plants.

The population in the southwest, while large, is quite dispersed. Many of the waterworks in this area are small: 157 facilities serve fewer than 1,000 people.

Figure 1-4 Geographic Distribution of Ontario Drinking Water Treatment Plants



Note: 30 plants did not report population served.

Source: Ontario, Ministry of the Environment, 2000g.

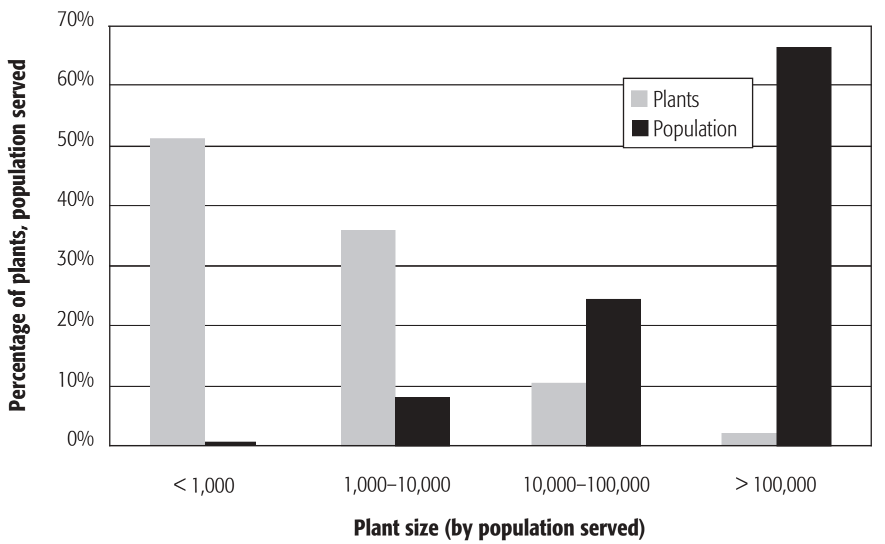
While the trend in many parts of North America is to merge several treatment and distribution systems to improve quality and supply, a large number of small individual systems remain in southwestern Ontario. This may present greater challenges to monitoring and promotion of uniform water quality for the population.

1.4.2 Size of Water Treatment Plants

It is recognized that the resources available to a water treatment facility might influence treatment performance. In the United States special rules aimed at small systems (serving fewer than 10,000 people) allow them to receive support for implementing advanced technologies, operator training, etc. (see chapter 5). Although drinking water standards ideally apply equally to all communities, some may be at a practical disadvantage when it comes to meeting rules or guidelines.

Many of Ontario's treatment plants are small; slightly more than half of all municipal waterworks serve fewer than 1,000 people each. Only about 15% serve more than 10,000 people each. Nevertheless, this 15% of facilities serves about 90% of the population (see figure 1-5). Drinking water treatment in Ontario is therefore quite heavily polarized: a large number of small treatment

Figure 1-5 Distribution of Drinking Water Treatment Plants and Population Served, by Plant Size



Source: Ontario, Ministry of the Environment, 2000g.

facilities serve a few people and a small number of large facilities serve many people. The positive aspect is that resources directed to the large treatment facilities will benefit the majority of Ontario's population. The negative aspect is that to provide the same quality to the remainder of the population, resources must be widely distributed among a large number of small facilities.

1.4.3 Treatment Technologies

The SWIP database does not provide detailed information on treatment methods used at the various plants in Ontario; however, it does list the presence or absence of some of the major processes.

Disinfection

figure 1-6 shows disinfection-use statistics. About 99% of the population of Ontario served by municipal treatment plants receives disinfected water. All of the larger plants (more than 100,000 people served) provide disinfection. However, only about 92% of facilities serving fewer than 1,000 people, report disinfection. Prior to the Drinking Water Protection Regulation there was no statutory requirement for disinfec0tion. The new regulation makes disinfection mandatory for all municipal water systems.[8]

Filtration

Historically, disinfection has been the process most relied upon to ensure safe drinking water. Other treatments have been used primarily to remove physical or chemical contaminants. The current approach to drinking water treatment recommends a multiple-barrier approach for surface waters, with chemically assisted filtration accompanying disinfection. This provides more than one line of defence against pathogens. Groundwater, which is less likely to be contaminated by pathogens, is less likely to require filtration. The Drinking Water Protection Regulation reflects this philosophy; it requires groundwater to be disinfected while surface waters must be disinfected and filtered (or an equivalent).[9]

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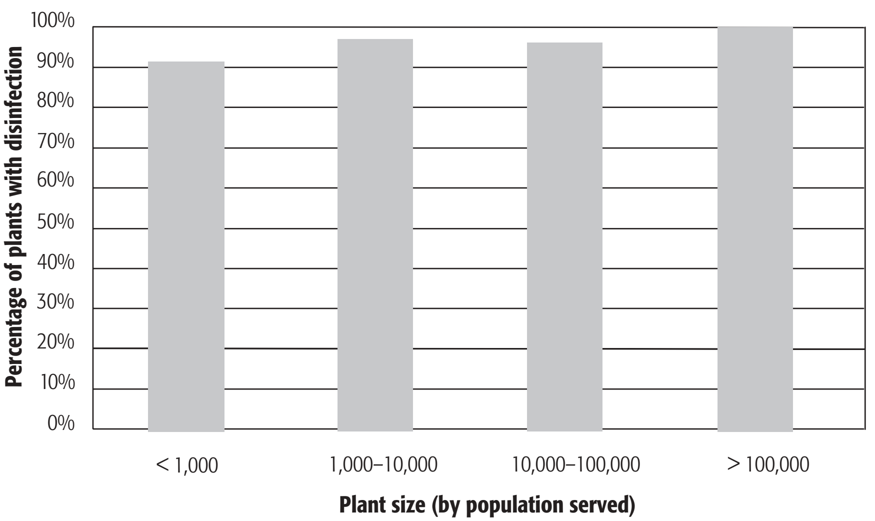
[6] Ontario, Ministry of the Environment, 2000a, *Ontario Drinking Water Standards* [online], PIBS 4065e (revised January 2001) [cited July 2001], <www.ene.gov.on.ca/envision/WaterReg/Pibs4065.pdf>. CT is the product of disinfectant concentration C and the contact time T. See *Standards,* procedure B13-3, sec 3.0, for a discussion of the concept.

Approximately 87% of Ontario's municipally serviced population receives filtered water, which corresponds roughly to the percentage of the population receiving treated surface water (see figure 1-2). However, not all surface water treatment plants report using filtration (see figure 1-7). In particular, about 50% of very small surface water plants (fewer than 1,000 people served) do not filter. In mid-sized plants (serving 1,000 to 100,000 people) filtration is more common: only 20% to 30% do not filter. Only 5% of large plants (serving more than 100,000 people) do not filter.

To comply with the Drinking Water Protection Regulation, all of these facilities are now required to install chemically assisted filtration or the equivalent.

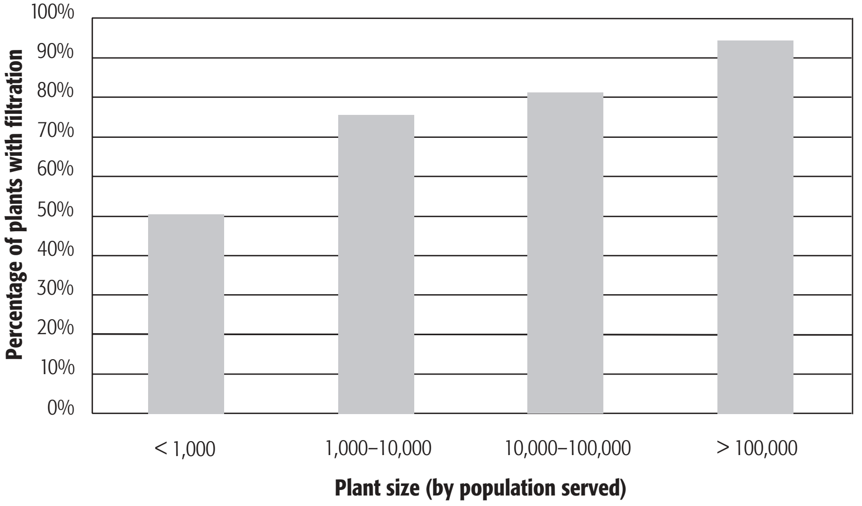
While filtration may not be necessary to make groundwater safe to drink, it can still be used to remove turbidity or precipitates. However, the vast majority of groundwater treatment plants do not filter (see figure 1-8), implying that these systems rely exclusively on disinfection to ensure protection against microbial contamination. This is not necessarily inappropriate, but it underscores the need to ensure that these sites have well-designed and routinely monitored disinfection processes.

Figure 1-6 Percentage of Treatment Plants Disinfecting Water, by Plant Size



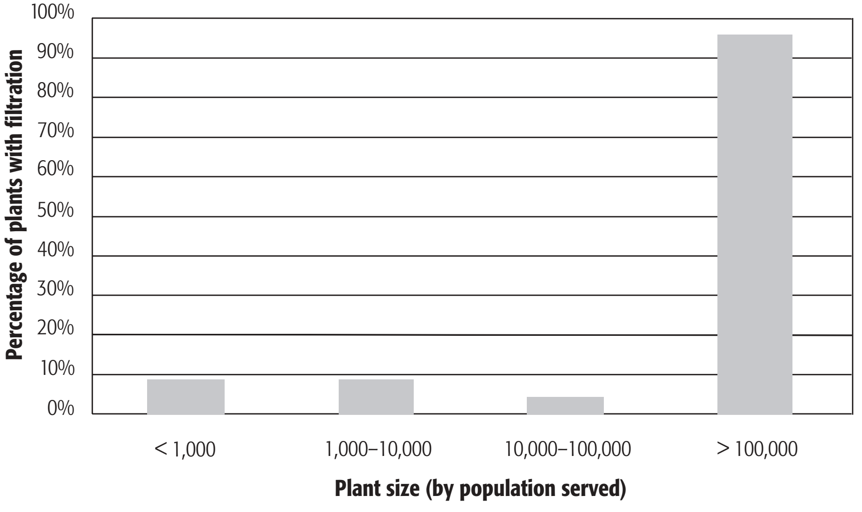
Source: Ontario, Ministry of the Environment, 2000g.

Figure 1-7 Percentage of Surface Water Treatment Plants that Use Filtration, by Plant Size



Source: Ontario, Ministry of the Environment, 2000g.

Figure 1-8 Percentage of Groundwater Treatment Plants that Use Filtration, by Plant Size

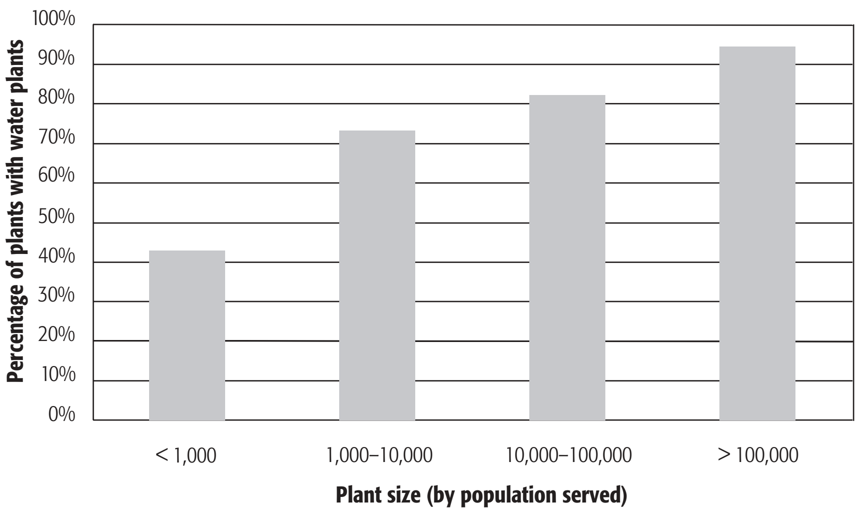


Source: Ontario, Ministry of the Environment, 2000g.

Coagulation

It is common practice to add a coagulant to water to enhance particle removal during sedimentation and filtration. Coagulation is normally used to treat surface waters, but rarely to treat groundwater. According to the SWIP database, only about 1% of Ontario groundwater treatment facilities apply coagulants. The reported use of coagulation in different-sized surface water plants follows the trend observed for filtration. Only about 45% of very small plants (fewer than 1,000 served) used coagulation (see figure 1-9). Approximately 80% of mid-sized plants used it, while almost all large plants serving more than 100,000 people used coagulation. The Drinking Water Protection Regulation requires that surface water treatment facilities provide "chemically assisted" filtration or an equivalent.[10] It may be anticipated that the number of facilities using coagulation will increase in response to the regulation.

Figure 1-9 Percentage of Surface Water Treatment Plants that Use Coagulation, by Plant Size



Source: Ontario, Ministry of the Environment, 2000g.

[7] See appendix 1, section A1.2.4.1, for information on how each barrier can be used and managed in a drinking water treatment system to manage risk effectively.
[8] Ontario legislation and regulations can be found on the e-Laws Web site <www.e-laws.gov.on.ca/home_E.asp>.
[9] E. Doyle et al., 2002, *Production and Distribution of Drinking Water* (Toronto: Ministry of the Attorney General), Walkerton Inquiry Commissioned Paper 8, Walkerton Inquiry CD-ROM,

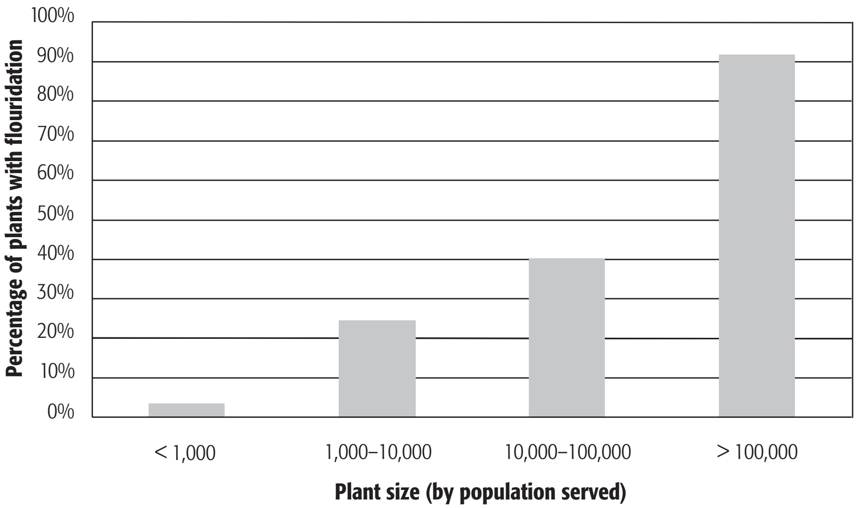
Fluoridation

Fluoride may be added to drinking water to improve dental health. While this process is sometimes controversial due to a perceived risk associated with addition of chemicals to drinking water, it is nevertheless common in most of Canada and the United States. In Ontario, 74% of the population on municipal water systems received fluoridated water during the period of SWIP monitoring. However, the size of treatment facility strongly influences the likelihood of fluoridation (see figure 1-10). Less than half the plants serving fewer than 100,000 people fluoridated the water. In contrast, 90% of large systems (more than 100,000 people each) used fluoridation.

1.5 Owners and Operators

Significant changes are taking place in ownership and operation of Ontario waterworks. Historically, the province played a major role in supplying drinking water to the public. However, in the last decade this responsibility has passed to municipalities and, in turn, to private or semi-private organizations. In particular, the *Water and Sewage Services Improvement Act,* passed in 1997, initiated the transfer of water and wastewater treatment facilities to the municipalities and

Figure 1-10 Percentage of Treatment Plants with Fluoridation, by Plant Size



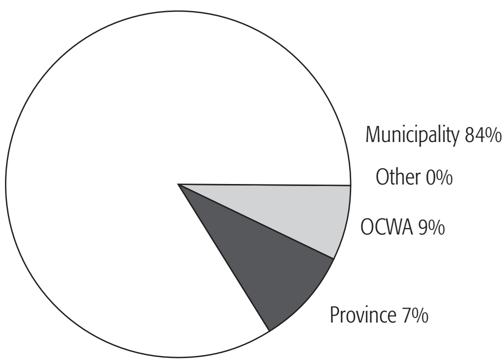
Source: Ontario, Ministry of the Environment, 2000g.

allowed the sale of facilities to the private sector.[11] The SWIP database, compiled partially during this transition, reports that in the mid-1990s, systems owned by individual municipalities served 84% of the population (see figure 1-11). The Ontario Clean Water Agency (OCWA), a provincial crown corporation, owned systems that supplied 9%, while the province reportedly owned systems that supplied 7%. Private organizations owned twelve systems. In the years since the SWIP database was created, the remaining provincially owned facilities were to be transferred to the municipalities.

Not all drinking water systems are operated by the owners. As shown in figure 1-12, individual municipalities operate systems that serve 73% of the population, while OCWA-operated systems serve 19%. Public utility corporations (PUCs) and other private organizations operate systems serving the remainder. The province does not operate any systems; its operational duties were transferred to OCWA in 1993.[12]

The role of municipalities as drinking water system operators may continue to decrease, with OCWA or fully private operators taking over. In response to the downloading of responsibility and ownership from the province in the 1990s,

Figure 1-11 Ownership of Drinking Water Treatment Plants as a Percentage of Population Served



Sources: Ontario, Ministry of the Environment, 2000g.
Note: Although 12 systems are owned privately in the "other" category, the population served is too small to register at this level of significant figures.

<www.walkertoninquiry.com>, sec. 3.4; and Australia, NHMRC/ARMCANZ Co-ordinating Group, 2001, sec. 7.

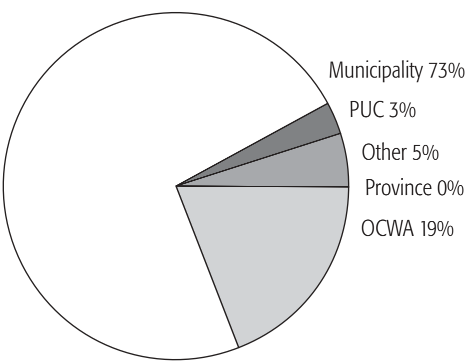
some municipalities decided that contracting operations to private organizations was preferable. Arguments in support of downloading include increased efficiency and elimination of perceived conflict of interest (i.e., the ministry regulating its own facilities). Counter-arguments include suggestions that downloading and privatization will increase fractionation and inequity among the province's waterworks. It is not the intent of this report to comment on the pros and cons of downloading and privatization. The data presented are intended to show that most of the waterworks in Ontario remain under the ownership and operation of municipalities, with OCWA, in particular, acquiring a larger share.

1.6 Water Quality Considerations

So far, this chapter has focused on factors that affect supply of high-quality drinking water to the population of Ontario. It is not the intent of this report to comment on the specifics of Ontario's water quality. However, the following information generally indicates the ability of existing facilities to meet Ontario's drinking water standards (formerly objectives).

The DWSP database provides a representative cross section of drinking water systems in Ontario. It includes large, small, urban, and rural systems. It distinguishes between those that supply water from surface and groundwater sources. In 1998 and 1999, 162 of the systems (approximately 26%) provided water samples to the ministry for analysis. The suite of parameters measured

Figure 1-12 Facility Operation of Drinking Water Treatment Plants as a Percentage of Population Served



Source: Ontario, Ministry of the Environment, 2000g.

included those listed in the drinking water objectives, as well as many others. More than 300,000 individual measurements were made under the DWSP during 1998 and 1999. Of those measurements, there were 91 instances when monitored parameters exceeded health-based objectives. See table 1-2 for the specific contaminants that exceeded the objectives.

While the DWSP monitored many potential chemical contaminants in drinking water, the only direct microbiological measurement routinely conducted was a standard plate count.[13] Such a measurement provides partial information about the microbiological quality of a water sample, but it is by no means definitive. It is possible, for example, for water to exhibit an acceptably low plate count while still containing harmful levels of pathogens such as protozoa or viruses, which cannot be measured using this technique.

Although the DWSP data indicate that the chemical quality of Ontario's drinking water is generally very good, the database should not be used to draw similar conclusions about the microbiological quality. This is not surprising. Microbiological sampling is much more time-sensitive and difficult to

Table 1-2 Health-based Objectives Exceeded during 1998–1999 DWSP Sampling Program

Contaminant	Instances when health-based objectives exceeded
Fluoride	8
Nitrate	2
Turbidity	38
Lead	10
Selenium	4
N-Nitrosodimethylamine (NDMA)	4
Chloramines	2
Trihalomethanes (THMs)	23
Total instances	**91**

Source: Ontario, Ministry of the Environment, 2000b.
Note: Only 26% of water treatment systems (162 of approximately 630) participated.

[10] Australia, NHMRC/ARMCANZ Co-ordinating Group, 2001, sec. 7.

coordinate than chemical sampling. In the past, the overall microbiological quality of drinking water was monitored through surrogate parameters or indicators, such as the standard plate count, or the concentration of residual chlorine in the water. It is only in recent years that the drinking water industry has begun to look more closely at how to detect harmful organisms. For example, in 1998 and 1999 the U.S. Environmental Protection Agency (EPA) undertook a program called the Information Collection Rule (see chapter 5), in part to collect more extensive microbiological data from drinking water supplies across the country. The EPA uses these data to assess regulations that target microbial contamination in drinking water. There is currently no equivalent to this program in Ontario.

1.7 Ontario Drinking Water – Summary

Before the Ontario Drinking Water Protection Regulation came into force, data collection from drinking water systems was voluntary and informal, except for regulatory monitoring. Of the databases that existed, the SWIP database focused on physical characteristics of treatment systems rather than on their performance. Data were typically collected once every two to four years from every system in the province. The DWSP database focused on water quality monitoring, with a very broad suite of parameters measured to track trends and assist in development of new water quality objectives. By 1999 the database included 26% of all waterworks in Ontario, a sample that was fairly representative of the province as a whole. As a result of the new regulation, all public drinking water systems must regularly provide water quality reports to the ministry. The data are compiled in an adapted form of the DWSP and SWIP databases.

According to the SWIP database, approximately 82% of Ontario residents receive water from municipal drinking water systems, the remainder from private wells. There were about 630 such systems in the mid-1990s, the majority of which used groundwater and served fewer than 10,000 people each. In contrast, a few large plants using surface water served most of the population. There is therefore a distinct polarization of drinking water services in Ontario: most of the population is served by large surface water facilities, but the rest is served by a great number of small systems scattered throughout the province. This may influence efforts to ensure consistent water quality for the population as a whole. To address a similar issue, the United States has developed assistance programs to ensure that small systems have adequate access to resources aimed at facilitating regulatory compliance, as discussed in chapter 5.

There is a reported disparity in the level of treatment offered by plants of different sizes. The frequency of disinfection, filtration, fluoridation, and coagulation all increase with increasing plant size. It is inappropriate to conclude that water quality in smaller systems is therefore inferior. Large systems require larger volumes of water and may be more restricted in their selection of good-quality source water and may generally require a higher level of treatment to produce excellent drinking water. Small systems may be located in areas with a wider selection of relatively pristine water sources, potentially requiring less treatment to achieve the same water quality. Nevertheless, the reported disparity in treatment technologies employed in smaller versus larger systems and the potential impacts on drinking water quality are interesting.

The challenges that face Ontario in meeting the government's stated goal of "having the safest water in Canada" are not overwhelming.[14] Perhaps no other province has such a large supply of easily accessible, clean water as Ontario, thanks to the Great Lakes. The DWSP data also suggest that for the most part Ontario drinking water systems already deliver water that exceeds the new standards. There is potential for problems, however, with the large number of small systems that could have difficulty in producing water of excellent quality. The trend toward privatization could also introduce challenges in maintaining parity throughout the province.

1.8 Staff Training

Water utility staff training is a legislated requirement for all water treatment operators, water distribution operators, and water quality analysts. The recently changed Ontario Regulation 435/93 requires that licensed operators and analysts have a minimum of 52 hours of training per year.

Staff training is required to ensure continual learning and skill development, and to make certain that staff have the knowledge and skills to carry out their job functions. Many other positions in water utilities are not covered under Ontario Regulation 435/93, yet have impacts on all aspects of services provided by the utilities. Personnel holding positions in administrative support, human resources, financing, maintenance, etc., also require training in their duties to

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[11] Ontario, Department of the Environment, 2000b, *Training Requirements for Sampling Drinking Water* [online] (fact sheet), [cited October 2001], <www.ene.gov.on.ca/envision/news/factdec6.htm>.

make certain that they have the knowledge and skills to perform their work effectively and efficiently.

All staff must be trained in health and safety issues related to their duties and to the environment in which they work.

A water utility must plan for staff training, including the commitment of appropriate financial support, staff time, facilities, material, and equipment. Staff training and development plans should be prepared for each individual staff member based on the job duties and the utility's current and future goals.

Training is an investment in human capital. Managers and the utility's board of directors must understand that investment in physical plant, modern machinery, and new technology cannot be fully realized without investment in human capital. The acquisition of new skills is vital to improving quality, productivity, and efficiency in any organization.

1.9 Operations, Maintenance, and Management Practices

The operation, maintenance, and management practices of water utilities across Ontario vary tremendously. This variation is based on numerous factors, such as size, type of operation (public or private), complexity of the facilities, type and quantity of source water, location (northern Ontario versus southern Ontario), levels of governance involved (region, city), and type of community (urban, rural). Such variation is not unique to Ontario and in fact is found across the water industry worldwide.

Although practices vary substantially, the push for efficient and effective practices has been a focus of the water industry over the past 10 years. This is principally due to large private water utilities seeing business opportunities arise where public utilities were either not meeting their customers' needs or not embracing new technologies and management trends to become more efficient.

New technologies and new management trends are often considered best practices. Chapter 3 specifically discusses the best practices of the various services provided by a water utility. Although the term is used in the business world, there is no agreed definition of best practices. Keehley et al. give three common definitions in *Benchmarking in the Public Sector*:

- anything better than the current practice
- anything defined as such by the media or other authority
- an award-winning success[15]

Best practices are typically

- successful over time,
- quantifiable,
- innovative,
- recognized for positive outcomes,
- reproducible,
- locally important and relevant, and
- not linked to unique demographics.

As stated, a best practice must be quantifiable and reproducible. This requires good measurement tools. The term 'benchmarking' is often linked to best practice for this reason. There are essentially two types of benchmarking: metric and process.

Metric benchmarking is usually a numerical value per quantifiable unit. For example:

- cost of water: $0.50 per cubic meter
- frequency of watermain breaks:
  - 1.2 breaks per 100 km per year
  - 325 breaks per year
- cost of energy: $0.02 per cubic metre (1,000 litres) of water delivered
- customer inquiries: 6.7 inquiries per 10,000 population per year

These internal benchmarks can thus be compared to external benchmarks (i.e., those of other utilities or similar industries). When benchmarks are compared both internally and externally, the utility and customers have the means to evaluate the performance of an activity, and of the utility.

Metric benchmarks can only identify areas that may be superior or inferior in performance. Process benchmarking, in comparison, is undertaken to evaluate

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[12] Australia, NHMRC/ARMCANZ Co-ordinating Group, 2001, sec. 7.2.
[13] Ibid.

and improve a specific activity. There are thousands of activities within a water utility, and metric benchmarks can help identify those inferior-performing activities that should be process benchmarked. Say, for example, that a metric benchmark for the activity of handling a customer inquiry reveals that a utility is substantially inferior to other, best-practice, utilities. The utility decides to undertake a process benchmark of this activity that would include all steps from the first contact with the customer (in person, by telephone, through the Internet, or by other means) to the point of actually dealing with the inquiry. In some cases, an inquiry can be taken and answered immediately; in other cases, work orders, repairs, and reinstatement work may be required.

Process benchmarking takes an activity, develops a 'map' of the process for that activity, collects data, identifies best-in-class benchmarking partners, makes site visits to those partners (specific to the activity), recommends improvement to the current activity, and adopts the changes.

If it followed all steps appropriately, the utility that undertook the process benchmarking initiative should now be a best practice utility in this specific activity. This is frequently how continuous improvement initiatives are undertaken in many industries (e.g., food, automotive).

Many water utilities and associations related to water utilities have researched and adopted best practices and continuous improvement initiatives. See chapter 3 for further discussion.

1.10 Costs of Ontario Water Treatment

1.10.1 Introduction

This section has two objectives. The first is to review and comment on the current level of costs and revenues in the water and wastewater industry in Ontario.[16] The second is to provide information on expected levels of investment that will be required in the future. Several existing studies on this subject provide a basis for examination and comment.

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[14] For further reading on the subjects of this section, a number of papers by contributing author

Some terminology should be explained. On the cost side there is a difference between operations, maintenance, and administration costs (collectively termed OM&A or 'operating' costs) and capital costs. OM&A costs relate to the operation of the system. They include such items as labour, energy, chemicals, and fees, and they are generally ongoing. Capital costs are one-time investments required to built facilities (infrastructure) such as treatment plants, storage, pumping stations, hydrants, service connections, and mains. Once built, the infrastructure must be maintained and repaired. Infrastructure repair is an OM&A cost, whereas infrastructure provision or replacement is a capital cost.

On the revenue and financing side, municipalities have a great deal of freedom to set water and wastewater user rates, to charge fees, or to use property tax revenues to support water and wastewater systems. But legislation is much more specific and detailed when it comes to paying the cost of infrastructure needed for system growth due to increasing population. Provincial legislation sets out what capital charges are allowable and limits how they must be calculated. Capital charges include frontage, connection, and development charges.

Above-ground facilities and below-ground facilities tend to be considered differently. Planning and cost estimation is usually easier for above-ground facilities, which comprise water treatment plants, water wells, sewage treatment plants, pumping stations, and storage. These facilities are visible, must be operated, and require ongoing maintenance. They are critical to good water quality and sewage treatment. They are the focus when it comes to regulating quality, and they were central to the inspections carried out in all water systems by the MOE in 2000.

Expansion and upgrading of underground facilities, which include mains and service pipes, tends to be more difficult because they are out of sight and, often, little is known about their age, materials of construction, or condition. This makes accurate cost estimation difficult.

The provincial government has jurisdiction over water supply and sewage treatment. During the 1990s it delegated these functions to municipalities, over which it has jurisdiction and whose responsibilities it defines. The province also enacts the legislation that defines how municipalities may recover water and wastewater system costs; it monitors municipal finances; and it requires annual financial reporting.

Annual financial reporting includes the Financial Information Return (FIR), submitted annually by every municipality. FIRs constitute the base information source for the current financial status of municipal water and wastewater systems in Ontario. The reports provide comprehensive information on expenditures and revenues by municipalities, including segregated information on water and wastewater systems. They can be used to extract factual information on the current water and wastewater system financial status. Some of the existing studies reviewed in this paper also quote FIR information. To clarify the approach used in interpreting the reported numbers, this section explains water utility financial reporting in general and the FIR in particular.[17]

Unless otherwise identified, the information presented in the tables and figures in this section is generated from data presented in the Sewage and Water Inspection Program database and from data provided by the Ontario Ministry of Municipal Affairs and Housing in response to requests by the author of this paper.

1.10.2 Organization of Financial Information Returns

FIRs divide costs into two categories: capital fund and revenue fund.

Capital Fund

The capital fund is fairly easy to understand. It provides information on how the cost of building or replacing capital facilities (infrastructure) is funded. It covers the cost of construction of all water and wastewater infrastructure built by the municipality. It does not include the cost of works built and paid for by developers (i.e., local servicing) or the costs of private property. The financing sources are revenue sources, reserve funds, and debt financing.

Revenue sources Revenue sources include user rates, property taxes, fees, grants, and capital charges. Some revenue sources, such as user rates and property taxes, first appear in the revenue fund (see following subsection) and a portion is transferred for use in the capital fund by means of an entry called “transfers to own funds.”

Bill Fields are listed in the reference section. Most of the material in this section, including tables, figures, and lists, are derived from those papers.

Reserve funds Funds from the revenue sources can be put aside in reserve funds to be applied when required. One such reserve fund comes from current revenues (referred to as "transfers to own funds" in the FIR). Another common reserve fund comes from development charges.

Debt financing Repayment of infrastructure cost can be delayed by means of debt financing, commonly referred to as debenturing, which spreads the cost of capital facilities over future years. Repayment includes the original principal borrowed plus interest charges.

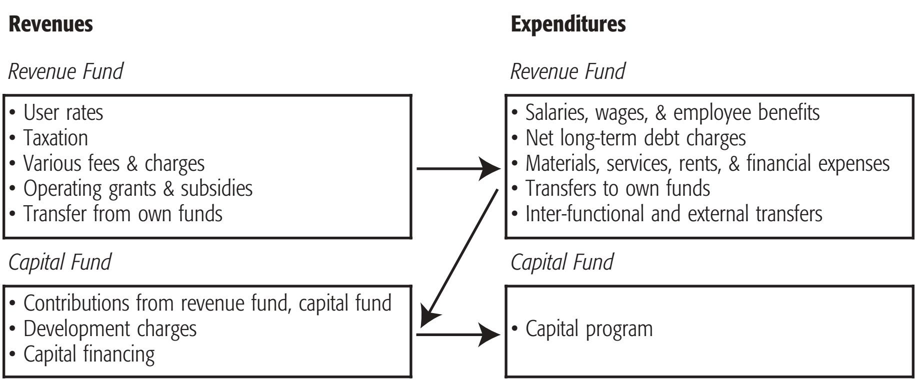
Unfortunately, FIR capital fund summaries for water and wastewater identify only grant information separately – all the municipal financing sources (revenue sources, reserve funds applied, and debt financing) are combined into one number.

Revenue Fund

The revenue fund statement reports on current expenditures, including OM&A costs, debenture debt, and transfers to own funds (essentially capital contributions), as well as payments for overhead charges or to other agencies. Information is also provided on user-rate revenues, charges, fees, and grants.

The costs reported in each of the capital and revenue funds, and the relationship between the two, are illustrated in figure 1-13.

Figure 1-13 Relationship between Revenue Fund and Capital Fund



Source: Ontario, Ministry of Municipal Affairs and Housing, 2000, *Financial Information Return* [online], [cited October 2001], <www.mah.gov.on.ca/FIR/index-e.asp>.

FIRs can be used to determine annual investment in Ontario water and wastewater systems, but not simply by adding the revenue fund and the capital fund – the total would overstate the capital investment. Although the capital fund reports actual cash outlays for capital investment in the year, the revenue fund also includes two capital-related items: “net long-term debt” and “transfers to own funds.” Because the capital fund represents capital investment before debt financing, double counting would result if the total included “net long-term debt” and the capital fund component financed through debenturing. Thus, net long-term debt charges are deducted from the total. And because the “transfers to own funds” portion of the revenue fund becomes a source of funds for the capital program, it is also deducted from the expenditure total.

The total annual expenditures are calculated as follows:

Cash expenditures = revenue fund + capital fund – transfers to own fund – net long-term debt charges.

A Note on Depreciation

Questions sometimes arise as to whether infrastructure depreciation costs are properly covered. The term is often used loosely to refer to the cost of replacement of facilities. If that were the meaning intended, a different, more precise term, such as ‘replacement costs,’ would be better. Depreciation in financial terms is the spreading of the original cost over the life of the item. Depreciation is not charged in the cash-basis accounting system used by Ontario municipalities.

In the water industry, two approaches are used to account for costs: the ‘cash’ basis and the ‘utility’ basis. Both methods treat operating, maintenance, and administration costs in the same way.[18]

Figure 1-14 illustrates the relationship between the cash and utility bases of accounting.

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[15] APQC worked in conjunction with AWWA and WEF to develop the QualServe program.

Municipalities across Canada commonly use the cash basis to report costs; it is the method used by Ontario municipalities. Expenditures are recorded based on actual cash outlays during the year. Capital costs are charged based on items such as debt repayment, capital outlays, and reserve fund transfers. Because Ontario municipalities use the cash basis for accounting, categories such as depreciation and return on investment are not reported.

1.10.3 Current Annual Investment

See table 1-3 for the 1997 water and wastewater revenue fund expenditures for all municipal systems in Ontario.

The total revenue fund expenditures for municipal water systems in Ontario was $910 million ($861 million for wastewater). "Inter-functional transfers" relate to overhead-type charges, and the "other transfers" are charges by outside organizations. The percentage share of each cost category is illustrated in figure 1-15.

Figure 1-14 Cash Basis versus Utility Basis of Accounting

Cash Basis	Utility Basis
Operations, maintenance, and administration (includes debt interest)	Operations, maintenance, and administration (includes debt interest)
Capital requirements • Debt principal • Capital expenditures from current revenues • Reserve fund transfers	Capital funds generated by • Depreciation • Return on investment, which includes profit

Table 1-3 Ontario Water and Wastewater Revenue Fund Expenditures, 1997 ($)

	Water	Wastewater
Salaries, wages, & employee benefits	191,479,876	133,268,118
Net long-term debt charges	77,615,831	152,259,721
Materials, services, rents & financial expenses	285,241,983	271,195,028
Transfers to own funds	289,761,292	258,362,368
Other transfers	8,253,602	8,870,270
Inter-functional transfers	58,078,782	37,510,222
Total	**910,431,366**	**861,465,727**

The wastewater debt load, at 18%, is much higher that the 9% in water systems. Total capital investment from current revenues (debt + transfers to own funds) is 48%, or almost half the revenues for wastewater, 41% for water. The difference is primarily made up in labour, where wastewater is lower at 15% compared with water at 21%.

The capital fund investment for water was $425,655,599 ($496,043,739 for wastewater).

See table 1-4 for the combined net cash outlays for water and wastewater systems in 1997. The table is constructed by adding revenue fund and capital fund outlays less "transfers to own funds" and debt charges, to avoid double counting. It would be preferable to leave debt charges in and deduct capital costs financed

Figure 1-15 Breakdown of Revenue Fund Expenditures

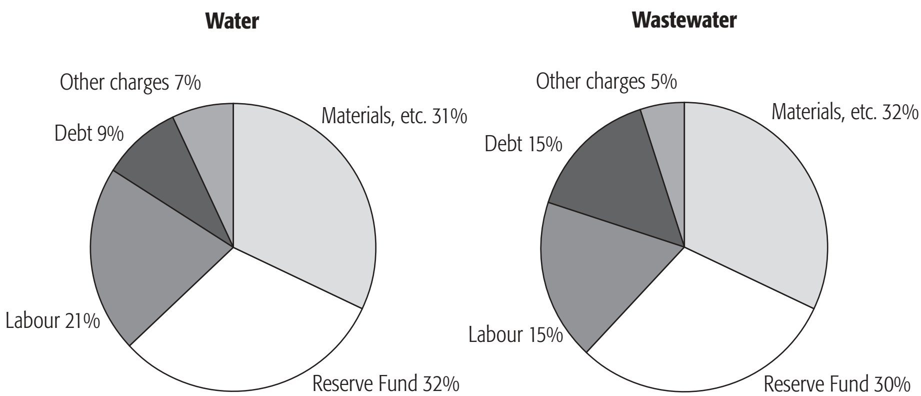


Table 1-4 Ontario Municipal Water and Wastewater Systems Cash Expenditures, 1997 ($)

	Water	Wastewater
Salaries, wages, and employee benefits	191,479,876	133,268,118
Materials, services, rents, and financial expenses	285,241,983	271,195,028
Other transfers	8,253,602	8,870,270
Inter-functional transfers	58,078,782	37,510,222
Capital fund	425,655,559	496,043,739
Total	**968,709,802**	**946,887,377**

by debenturing, but, as this information is not available, the debt adjustment is used as an approximation.

Thus, the total 1997 expenditure by municipalities in water systems was about \$969 million, of which, \$426 million, or 44%, was capital investment (see figure 1-16). For wastewater the total capital investment was \$496 million, or 52% of total outlays. Note that these figures do not include the cost of facilities contributed by subdividers, which would be recovered from the sale of property.

1.10.4 Cost Recovery

A summary of revenue sources is provided in table 1-5

The outside contributions by means of grants are not large and have been decreasing. See figure 1-17 for the percentage contribution of the various revenue sources.

Note that there is a greater reliance on property taxes for wastewater system funding, at 12% of revenues. This is likely because sewer costs were historically recovered from property taxes. When the regions were formed in the 1970s, they chose to move to a more user-pay approach with a shift toward a sewer surcharge. It appears that the transition is still not complete. There is actually some justification for including some water costs – the portion that provides for fire protection – on the property tax. Many municipalities do this; it is a

Figure 1-16 Breakdown of Total Water and Wastewater Cash Expenditures, 1997

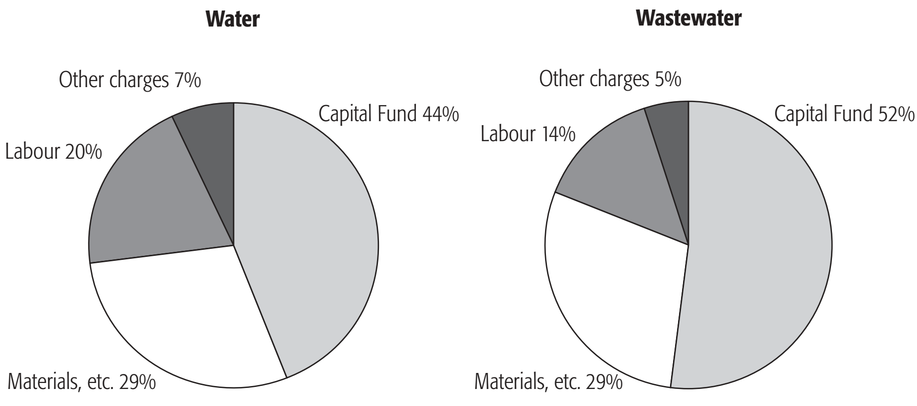
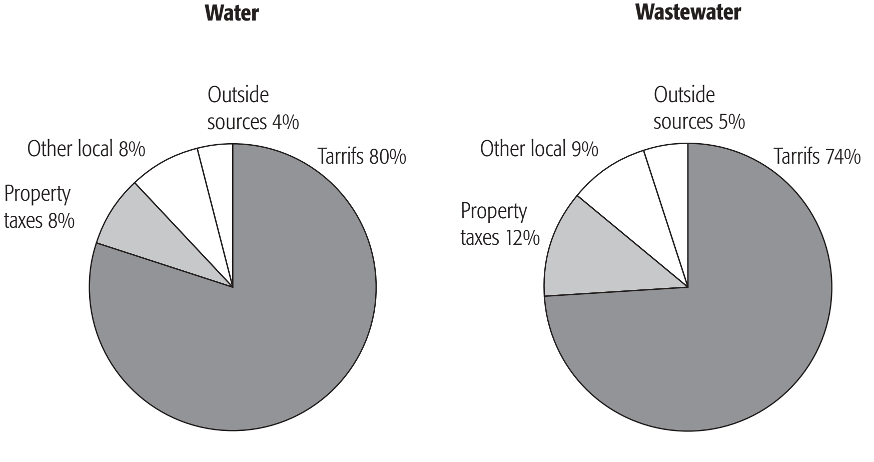


Table 1-5 Ontario Municipal Water and Wastewater Systems Funding Sources, 1997 ($)

	Water	Wastewater
Local financing		
User rates		
Residential	480,393,724	420,345,959
Non-residential	296,916,281	276,421,883
Total user rates	777,310,005	696,767,842
Other local sources		
Fees	29,993,896	32,450,278
Other (including property taxes)	79,563,776	117,401,066
Municipal contribution	31,005,494	18,166,605
Net financing (net impact of application or accumulation of reserve funds, including development charge receipts)*	12,414,386	37,449,579
Total local financing	**930,287,558**	**902,235,369**
Outside contributions		
Ontario grants	34,178,148	41,187,893
Canada grants	4,244,096	3,464,115
Total outside contributions	**38,422,244**	**44,652,008**
Total (local and outside)	**$968,709,802**	**$946,887,377**

* The net financing is the residual after other known revenue sources are deducted. It is a combination of the net inflow and outflow of reserve funds and the difference between debt repayment and financing. The details of these transactions are not reported for water and wastewater.

Figure 1-17 Ontario Municipal Water and Wastewater System Funding Sources, 1997



legitimate approach supported by the AWWA and allowed in provincial legislation. There is no parallel for sewers.

Analysis of 1997 revenue sources reveals that fully 96% of water revenues and 95% of sewer revenues are from local sources. Only $38 million, or 4%, of water revenues and $45 million of sewer revenues came in the form of grants from outside sources. Thus, most of the costs are locally funded. Whether or not sufficient investment is currently being made in municipal water systems may be questioned. However, the recovery of current investment levels is very close to full cost recovery

The concept of recovering water and wastewater system costs as much as possible through user rates is often promoted. Advantages include the promotion of conservation and clearly visible costs.

There are also other legitimate user-pay methods of cost recovery. Capital costs are often recovered up-front for new servicing through frontage and connection charges, development charges, and contributions by developers. And other fees and charge revenues are based on services rendered. Thus, it should not be assumed that user rates should be carrying the total burden for water and wastewater costs.

1.10.5 Size of Populations Served

The province has jurisdiction over municipalities and establishes the municipal jurisdictions responsible for the supply and delivery of municipal water and wastewater services. Municipalities are categorized by population size. Villages vary from a few hundred to a few thousand. Towns can have as many as 20,000. Cities vary from about 15,000 up. And there are regional governments. table 1-6 shows the number of municipalities served by municipal water systems – by category and estimated population.

Approximately 30 years ago the province established a number of regional or district governments, which assumed responsibility for the municipal water supplies in their areas. Most were single-tier systems, in which the region provides water distribution as well as supply. Some were two-tier, with the upper-tier region providing only supply and the lower-tier area municipalities retaining water distribution and retail billing responsibilities. Thirteen regional water authorities provide water to about 72% of the province's population served by municipal water systems. The largest, Metropolitan Toronto, has now been amalgamated into a single city.

The 23 cities have an average population of about 68,000 and are responsible for 19% of the serviced population. Towns represent 35% of the serviced local municipalities and have an average serviced population of about 6,000. They provide service to about 8% of the population. Villages average about 1,200 in serviced population and make up 28% of the serviced municipalities, but serve only the remaining 1% of the serviced population.

The province has established, and runs, several area water supply schemes that feed a number of towns and cities in southwestern Ontario from Great Lakes sources. Several of the larger municipalities are on area water-supply systems, including Sarnia (Lambton Area Water System), St. Thomas (Elgin AWS), and London (London Lake Huron AWS). Other area systems include Essex County (Union AWS) and the Blenheim AWS.

1.10.6 Per Capita Costs

The FIR revenue fund expenditure data have been analyzed to determine unit costs. At the time of the analysis, water capital fund data were not available by municipality. The serviced population data were obtained from the MOE. See table 1-7 for the per capita water costs for different categories of municipality and for surface water versus groundwater sources. Note that the analysis excludes municipalities where less than 90% of the supply comes from either surface or groundwater sources. Note also that costs are reduced to a common per capita

Table 1-6 1997 Municipal Water Systems and Population Served

Municipal level	Number of water supply authorities	Local municipalities		Population served	
		(N)	(%)	(N)	(%)
Regional systems					
Single tier	9	59	19	2,654,900	32
Two tier	4	34	11	3,265,200	40
Cities	23	23	7	1,572,700	19
Towns	110	110	35	656,800	8
Villages	84	84	28	103,000	1
Total	**229**	**309**	**100**	**8,252,600**	**100**

basis for comparison. Flow data would have provided additional insight but were not available at the time the analysis was carried out.

Surface water supplies 88% of the population and consumes 87% of the expenditures.

The surface water unit costs are lower for the larger municipalities and higher for small municipalities. The single- and two-tier annual per capita costs are almost the same, at about $94. The highest is for villages, at $171.

The groundwater unit costs do not follow the same pattern as the surface water unit costs. For the regions, the higher unit costs for groundwater are not too surprising because the surface water regions are large (dominated by Toronto) and the groundwater regions are much smaller. The groundwater annual per

Table 1-7 Ontario Surface and Groundwater Source Cost Comparison, 1997

	Authorities	Revenue fund expenditures ($000)	Population served	Per capita unit cost ($/yr.)
Surface water				
Regions				
Single tier	4	199,974	2,118,314	94
Two tier	2	278,448	2,940,833	95
Cities	17	145,185	1,290,121	113
Towns	55	41,686	350,028	119
Villages	25	6,807	39,837	171
Total surface water	103	672,100	6,739,133	100
Groundwater				
Regions				
Single tier	1	10,898	60,425	180
Two tier	1	41,896	324,335	129
Cities	4	19,867	242,525	82
Towns	37	22,822	200,442	114
Villages	47	5,852	53,789	109
Total groundwater	**90**	**101,335**	**881,516**	**115**
Total*	**193**	**773,435**	**7,620,649**	**101**

* excludes mixed surface and groundwater systems.

capita costs (as expected, because of lower treatment requirements) are substantially lower than surface water supply for cities ($82 and $113, respectively) and for villages ($109 vs. $171). For towns, the annual per capita costs are similar for groundwater and surface water sources ($114 vs $119).

1.10.7 Distribution of Unit Costs by Municipality Size

Regions

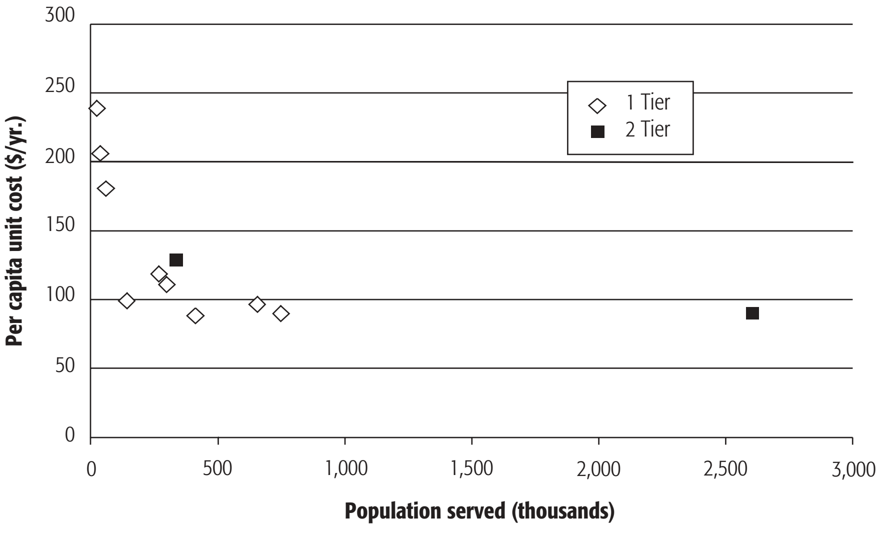
The single-tier regions – where the region has responsibility for both supply and distribution of water – include Durham, Haldimand Norfolk, Halton, Hamilton Wentworth, Ottawa Carleton, Peel, Muskoka District, and Oxford County.

The two-tier regions – where the local mains are provided by the area municipalities –include Metro Toronto (now the City of Toronto), York, Waterloo, and Niagara.

See figure 1-18 for a profile of regional unit water costs.

Although the regional system per capita costs are the lowest on average, within this category the two-tier system costs are a little higher, and small systems

Figure 1-18 Ontario Water System Expenditures for Regions, 1997



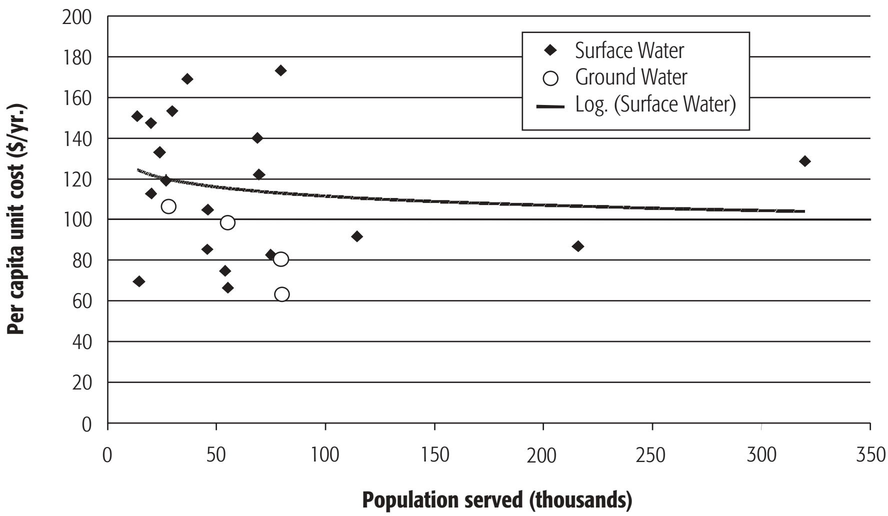
have higher unit costs than the larger systems. The largest municipality is actually a combination of Toronto and York, since much of York's water is purchased from Toronto. The two-tier regions of Waterloo and Niagara are similar in size and, having almost coincident cost levels, appear as one point on the graph.

Cities

Many of Ontario's largest cities are located within the regions – 23 are not. See figure 1-19 for those cities not in regions.

A regression analysis of surface water costs shows a trend toward lower annual costs for larger systems, ranging from about $120 per capita for a smaller system (population 30,000) to about $105 per capita for a population of 300,000. On an individual basis, there is a wide spread in unit costs. The groundwater supplies tend to be less expensive on average than the surface water supplies. The largest municipality, London, has a remote water supply (from Lake Huron), which may explain its higher-than-trend-line cost. Most of the low-cost systems are in Northern Ontario, including Timmins ($75), North Bay ($66) and Elliott Lake ($70).

Figure 1-19 Ontario Water System Expenditures for Cities, 1997



Towns

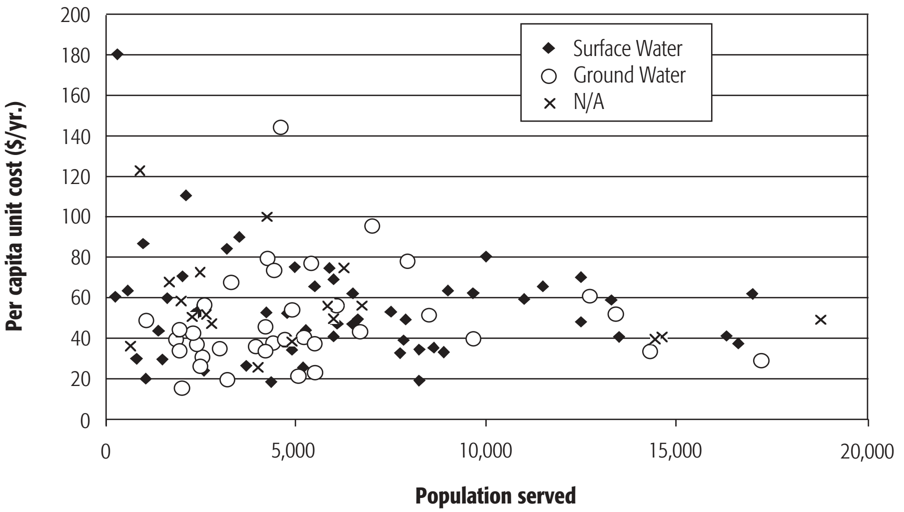
Of the 110 towns with water systems, 55 are served by surface water, 37 by groundwater, and 18 did not have their source specified in the database. See figure 1-20 for the per capita cost analysis for towns.

It is interesting that there is no apparent difference in unit costs between surface water and groundwater sources and no obvious difference between small and large municipalities. There is also a considerable spread in costs, particularly for towns with fewer than 10,000 people served.

Villages

Villages have populations up to about 10,000, although the largest has 19,000. The average 1997 water system revenue fund expenditure level for the 86 villages was $165,000. Unit per capita water costs are plotted in figure 1-21. In the case of villages, the smaller municipalities tend to spend less than the larger ones.

Figure 1-20 Ontario Water Systems Expenditures for Towns, 1997

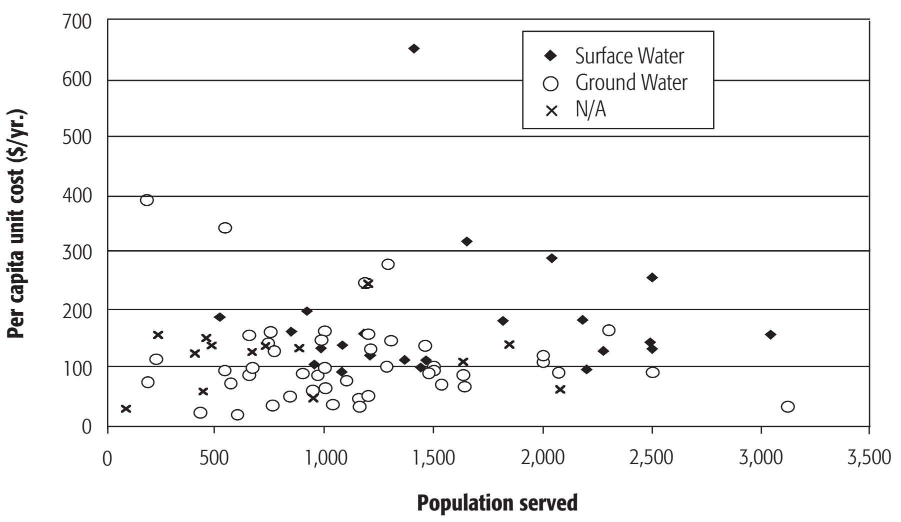


1.10.8 Future Investment Requirements

A number of studies have focused on the question of future water and sewer investment needs in Ontario. Their findings vary, which is not surprising given the lack of detailed knowledge of current conditions and historical infrastructure investment. It is apparent that there can be no single answer and that there are many unknowns. In fact it is not feasible to arrive at a definitive result. Consideration of individual municipal capital plans illustrates this clearly. Municipalities can only estimate their capital programs for the following year, and their five-year plans often bear little relationship to reality. Actual costs for projects can vary widely from estimates, particularly since projects are often delayed or postponed. Furthermore, cost estimates for projects that deal with rehabilitation or expansion of sewers or watermains cannot be finalized until the pipes are exposed. Most municipalities lack detailed knowledge of the age, material, or condition of underground infrastructure. Consequently, province-wide totals of such estimates, using limited factual information, are unlikely to be consistent.

Note also that studies vary in the infrastructure standards expected to be achieved. Examples of assumed variables include level of treatment, quality

Figure 1-21 Ontario Water Systems Expenditures for Villages, 1997



of facilities, changes in servicing standards (increasing populations using existing infrastructure), technological standards, growth rates, and degree of servicing.

Following are summaries of five studies conducted to estimate future investment levels needed in Ontario water and sanitary sewer systems.

Ontario Ministry of Environment and Energy (1996)

A draft paper, prepared for discussion, included estimates of Ontario water and wastewater investment requirements. There is no indication that the information in this paper achieved any official status, and it may have been subsequently changed. However, the information is worth noting, as it appears to result from a detailed analysis of the actual condition of water and sewage treatment facilities in Ontario (see table 1-8).

Table 1-8 Water and Wastewater Treatment Plant Infrastructure Needs 1995–2005 ($ Millions)

	Deficiencies	Rehabilitation	Growth	Total
Wastewater treatment plants				
Upgrade 21 primary treatment plants to secondary	746			746
Offset flow capacity deficiencies	595			595
1995 to 2000		785	492	1,277
2000 to 2005		911	671	1,582
Total wastewater	**1,341**	**1,696**	**1,163**	**4,200**
Water treatment plants				
Offset flow capacity deficiencies	329			329
1995 to 2000		376	229	605
2000 to 2005		535	376	911
Total water	**329**	**911**	**605**	**1,845**
Total	**1,670**	**2,607**	**1,768**	**6,045**

Source: Ontario, Ministry of the Environment and Energy, Economic Services Branch, 1996, *Infrastructure Need for Water and Sewage Treatment Services in Ontario 1995–2005*, [draft paper, April 9, 1996] (Toronto: MOEE).

The paper, which does not deal with underground infrastructure, advances the philosophy of full-cost pricing – that all water and wastewater costs should be recovered solely from user rates. Using FIR data for 1993, the differential between user-rate revenues and revenue fund expenditures is calculated (see table 1-9). The unit rate is based on a total flow of 1.84 billion m^3. The differential of $435 million is offset by other revenue sources, primarily property tax revenues, but including as well other fees, charges, and grants.

The paper also calculates the impact on user rates of recovering the annual operating deficit plus the $6,045 million in capital costs for the infrastructure needs outlined in table 1-8. The capital costs are financed over 40 years at 7.75% interest, giving an annual capital cost requirement of $493 million ($342 million for wastewater and $151 million for water treatment).

Table 1-9 Water and Wastewater – Differential between Revenue Fund Expenditures and User Rate Revenues, 1993

	($ Millions)	($/m³)
Expenditures	1,707	0.93
User Rate Revenues	1,272	0.69
Differential	**435**	**0.24**

Table 1-10 Impact on User Rates of Full-Cost Recovery

	($ Millions)	($/m³)
User-rate revenues	1,272	0.69
Differential	435	0.24
Wastewater treatment*	342	0.19
Water treatment*	151	0.08
Total	**2,200**	**1.20**
Required user-rate increase	+73%	

Source: Ontario, Ministry of Environment and Energy, 1996.
*Based on the traditional MOEE financing approach of 40-year debentures, in this case using an interest rate of 7.75%. This long repayment period is counter to current financing practice. In any case, municipalities are unlikely to finance expenditures related to rehabilitation.

The report concludes that user rates would have to be increased on average in the province by 73% to meet the objective of recovering both the costs now recovered from other revenue sources and the anticipated capital costs (see table 1-10). The analysis includes the cost of growth, but does not take into account the effect of growth on revenues or revenues from capital charges such as frontage and connection or development charges. It does not include an allowance for additional future capital costs for underground infrastructure works.

Canadian Water and Wastewater Association (1998)

Municipal Water and Wastewater Infrastructure: Estimated Investment Needs 1997 to 2012 was prepared by the CWWA with support from the Canada Mortgage and Housing Corporation (CMHC). This report estimated annual Canadian investments in municipal water and sewer systems at $1.84 billion for water and $4.09 billion for wastewater, for a 15-year total of $27.6 billion and $61.4 billion, respectively. The estimates were based on extending water and sewer servicing to all urban residents, meeting the Canadian Drinking Water Guidelines, separating storm and sanitary sewers, and achieving wastewater treatment to Level III (tertiary) standards.

The report uses information from an Environment Canada municipal survey to calculate investment needed to expand water supplies to achieve full urban servicing. In 1994, approximately 9.3 million people or 85% of the Ontario population (10.9 million) lived in municipalities with populations greater than 1,000. In these municipalities, approximately 91% had water supply and 89% had sewage treatment.

The report estimates that an additional 3,862 km of watermains would be required to expand water supplies to the unserviced urban population. This was based on providing 1 km of mains for every 193 people served.

The serviced population growth was then projected at 30% over 15 years. This would lead to a servicing requirement for an additional 2,783,915 people, which translates to 14,424 km of mains. Estimates also included requirements for additional water storage tanks and water supply system construction to handle basic upgrades, major new systems, and growth.

Parameters used to calculate the future investment requirements included the following:

- 0.6% of the existing system is replaced annually.
- Mains expansion would cost $200/m. Replacement, including restoration, would cost $300/m.
- Water supply expansion would cost $2,000 per capita. Base upgrades would cost $300 per capita, major upgrades, $400 per capita.

See table 1-11 for the total estimated water investment requirements over the 15-year period.

Note that the estimates did not specifically identify current water system deficiencies. Reference to water supply upgrades does not differentiate between deficiencies and rehabilitation, and the cost is estimated over the 15-year period. Below-ground facility and storage tank estimates are only for ongoing rehabilitation or growth.

Ontario Sewer & Watermain Construction Association (2000)

OSWCA commissioned an independent study by PricewaterhouseCoopers with the following objectives:

- Undertake a high-level, independent assessment of the percentage amount that user fees would have to be increased to achieve full-cost pricing in Ontario's water sector.[19]

Table 1-11 Ontario Water System Investment Requirements, 1997–2012 ($ Millions)

	Replacement	Expansion	Growth	Total
Mains	1,163.7	1,495.5	2,884.8	5,543.9
Storage	315.9	36.6	137.4	489.9
Supply	1,110.0	298.2	5,120.5	6,528.7
Total	**2,589.6**	**1,830.3**	**8,142.7**	**12,562.6**
Annual	172.6	122.0	542.8	837.5

Source: Canadian Water and Wastewater Association, 1998, *Municipal Water and Wastewater Infrastructure: Estimated Investment Needs 1997 to 2012* (Ottawa: CWWA).

[16] See also Doyle et al., 2002; and Martin, Archer, and Brill, 2002.

- Identify preliminary mitigation strategies for addressing the impact of full-cost pricing.

The OSWCA study used the 1998 CWWA study for costs and the Ontario FIR database from the Ministry of Municipal Affairs and Housing. The study accepts the CWWA water cost projections, but reduces the sewer cost projections in the area of combined sewer separation.

Using 1997 data as an example, the analysis found that a user rate increase of 31% would be required to put water and sewer financing on a sustainable footing using full-cost pricing (see table 1-12).

Storm sewer costs are included in the sewer analysis. This is curious because storm sewer costs are not recovered on a user-pay basis in Ontario and are not included in the CWWA figures to arrive at the required level of "sustaining

Table 1-12 Analysis of Full-Cost Pricing Requirement, 1997 ($ Millions)

	Water	**Sewer**	**Total**
Revenues			
Direct billings	780.2	722.9	1503.1
Fees & service charges	31.6	38.6	70.2
Special charges	12.4	12.4	24.8
Total revenues	**824.2**	**774.0**	**1,598.2**
Operating costs			
Salaries & wages	191.5	147.8	339.3
Net long-term debt charges	78.3	171.1	249.4
Materials, services, rents, fin. exp.	287.8	288.5	576.4
Other transfers	8.3	8.9	17.2
Interfunctional transfers	58.1	43.5	101.5
Total operating costs	**624.0**	**659.8**	**1,283.8**
Available for capital investment	200.2	114.2	314.3
Sustaining capital expenditures			
Replacement	98.1	400.8	498.9
Expansion	163.9	144.5	308.4
Total sustaining capital expenditure	**262.0**	**545.3**	**807.3**
Additional funding required	61.8	431.2	492.9
Required user rate increase	7.5%	55.7%	30.8%

Source: Ontario Sewer and Watermain Construction Association, 2000, *Full Cost Pricing Gap Review of the Ontario Water Sector* (prepared by PriceWaterhouseCoopers) (Toronto: OSWCA).

capital expenditures." However, removing storm sewer costs from the revenues and operating costs figures does not appear to affect the results to any degree.[20]

State of Ontario's Water Infrastructure (May 2000)

This paper by George Powell provided the following estimate of annual Ontario water and wastewater rehabilitation needs:

- *Renewal and rehabilitation* – The worth of Ontario's water and wastewater infrastructure is estimated at $50 billion: $35 billion below ground, $15 billion above ground. Based on a 75-year life for below-ground facilities and 35 years for above-ground facilities, the replacement cost would be $0.895 billion annually ([35 ÷ 75] + [15 ÷ 35]).

- *Upgrading* – An MOE needs study completed in the early 1990s identified upgrading needs of $19 billion over 15 years, or $1.3 billion annually, broken down as follows:
  - safe drinking water initiative: $2 billion
  - universal metering: $0.5 billion
  - water and wastewater infrastructure rehabilitation catch-up: $3 billion
  - wastewater requirements: $13.5 billion

  If 50% of the catch-up costs are considered to be for water, the average annual cost would be $0.267 billion for water, $1 billion for wastewater.

- *Growth* – Although growth-related costs are normally recovered through capital charges to new house owners, there will be an impact on annual expenditures of about $100 million. This is equivalent to annual capital spending for water and wastewater of $2.3 billion.[21]

Association of Municipalities of Ontario (2000)

In June 2000 the AMO issued *AMO Action Plan – Protecting Ontario's Water.* The action plan promotes "a renewed, re-defined partnership between the

[17] Clean Water Action, Clean Water Fund, and California Public Interest Research Group Charitable Trust, 2001, *Measuring Up II – An Evaluation of Water Quality Information Provided to Consumers in California* (San Francisco: CWA).

municipal order of government, the provincial order of government, and the federal government." The AMO wants the provincial government "to recognize the important role of municipalities in planning and managing effective services in Ontario's communities."

Support material for the conclusions includes a figure for investment requirements: "The Ontario Jobs and Investment Board (OJIB) estimates that a five-year rehabilitation program to address the municipal infrastructure deficit for sewer, water, roads and bridges will cost $21.1 billion. Of this amount, $9.1 billion is needed for rehabilitation investment in Ontario's water and sewer systems alone."[22]

The action plan does not really focus on the level of costs or the method of cost recovery. It is more oriented toward overall policies to address water and wastewater system management and planning.

1.10.9 Summary Comments on Cost Data

Current Investment Levels

In 1997 the total cash outlays by municipalities for water and wastewater systems were $969 million and $947 million, respectively. The proportion allocated to capital investment in infrastructure was $426 million for water (44% of the total) and $496 million for wastewater (52%). These figures do not include facilities contributed by developers who recover the cost from sales of property.

Current Cost Recovery Levels

In 1997 revenues from local sources recovered 96% of water costs and 95% of wastewater costs. The remainder was paid by grants, mostly provincial. Thus, the municipalities are close to full cost recovery if grants are considered the only revenue source not part of full cost recovery. User rates recovered 80% and 74% of water and wastewater costs, respectively, with much of the remainder coming from property taxes. Development charges were also a factor, although their impact across the province appears to be minor. However, the statements

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[18] The full implementation manual for HACCP in the food industry can be found at the Canadian Food Inspection Agency Web site [cited December 2001], <www.cfia-acia.agr.ca/english/ppc/psps/haccp/haccpe.shtml>.

did not provide this breakdown. Most of the local revenue sources could be considered 'user pay.' In water systems, tying the property tax charge to the cost of providing water for fire protection is an accepted method of recovering these costs. It would appear that there is room to increase wastewater user rates to include the costs now recovered from property taxes. To accomplish this, wastewater tariffs would increase on average 16%.

Large Systems Serve 91% of Population

The population of Ontario serviced by municipal water systems in 1997 was about 8.9 million. Most of these systems are provided by regional governments (72% of the population served) or by cities (19%). Of the remaining population served, 8% are in towns and 1% in villages. Towns generally have a population of about 10,000, villages up to a few thousand. Although the population served in the towns and villages is small, the number of municipalities is large: towns represent 35% of the local communities serviced, villages 28%.

Per Capita Cost – Surface Water Source

Surface water sources are used in 88% of the municipalities.[23] The per capita annual cost for the revenue fund expenditures varies from $94 in the largest systems to an average of $171 in villages. The overall average cost for surface water systems is $100 per capita per year.

Per Capita Cost – Groundwater Source

Although it supplies water to only 12% of the population served, groundwater was used by 90, or 47%, of the 193 municipalities analyzed. The unit costs are high for the regional systems (Waterloo, for example, at $129 per capita, due to difficult water supply challenges, and Oxford County, at $180). The costs for cities, towns, and villages average from $82 to $114 per capita and are all lower than the corresponding treatment costs for surface water.

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[19] Australia, NHMRC/ARMCANZ Co-ordinating Group, 2001, sec. 2.3.

[20] See appendix 1, sec. A1.2.2, for a thorough discussion of hazard identification and risk assessment as per the Australian Framework. It includes a methodology for qualitative computation of risk (identifying high- and low-risk hazards).

[21] See appendix 1, table A1-1.

[22] Australia, NHMRC/ARMCANZ Co-ordinating Group, 2001, sec. 3.2.

Cost Categories

It is particularly important to identify and recognize the differences between various types of infrastructure costs. These differences can affect the timing of expenditure and the options for cost recovery.

Future infrastructure investments can be divided into three categories:

Deficiencies – These are investments needed immediately to bring facilities to current standards. Relating primarily to treatment facilities, they address improved standards, flow capacity deficiencies, and failure to meet current standards.

Rehabilitation – Relates to replacement of facilities as they wear out, this type of investment is already ongoing in water and sewer systems. The concern is whether current levels of investment are sufficient. The prevailing view is that they are not and that as systems age the amount required will escalate further.

Growth – This relates to increases in the number of customers served resulting either from servicing existing but previously unserviced urban population or from population growth. The CWWA estimates differentiate between the two.

For deficiencies that relate to water quality, the investments are of high priority and should be expended as soon as possible. They could have a direct result on current expenditure levels and cost recovery. On the other hand, growth-related

Table 1-13 Summary of Ontario Infrastructure Needs Studies ($ Millions)

	Deficiencies	Rehabilitation (annual)	New servicing (annual)	Comments
MOE (1996)	329 total	91.1	60.5	Treatment plants only – material not official
CWWA (1998)	n/a	172.6	665	Widely quoted study. Deficiencies not identified separately.
OSWCA (2000)	Accepts CWWA figures			
Powell (2000)	267 /year	497	550	Powell is considered authoritative, and earlier estimates by him have often been quoted.
CMA/OJIC (2000)		910	–	Taken as 50% of water and wastewater total spread over 5 years

costs may have little impact on user rates because Ontario has mechanisms to recover these costs directly from the customers who benefit.

Infrastructure Deficiency Studies

The various sources of information reviewed provide a range of estimates for infrastructure investment needs in Ontario (see table 1-13).

The following comments on the results of the infrastructure studies are offered.

Deficiencies

Deficiencies discussed in the reports generally relate to water supply issues. Repair of below-ground facilities is considered more of a long-term rehabilitation issue than one of obvious deficiencies. The 1996 MOE estimate is the only one that provides a snapshot of outstanding items that should be fixed immediately. Although it provides detailed information, it is now outdated. Some of the problems have been rectified, but there are now new standards to meet.

During 2000 many MOE inspections and engineers' reports on water supply plants in Ontario were completed. This information should provide a good basis on which to develop accurate estimates of the scope and cost of repairing outstanding deficiencies. The recently completed inspection program of all water treatment plants in the province reported that deficiencies exist in 357 plants. A review of the public notices of infractions reveals the following categories and frequencies of deficiencies:

- insufficient number of bacteriological or chemical samples being taken and analyzed (205 plants)
- inadequate disinfection equipment (74 plants)
- plant operators not appropriately certified or with inadequate training (59 plants)
- failure to comply with minimum treatment guidelines – including groundwater plants not chlorinating the water and surface water plants not treating the water with coagulation, flocculation, and filtration (59 plants)

For the first three deficiency categories, the cost of remediation should not be significant. For example, the Region of Durham estimated additional annual costs of $800,000 for sampling and testing and other measures to meet new water treatment standards in a total current water budget of $45 million. This is less than 2% of operating costs. The last category goes beyond training, sampling, and chlorinator repair. The costs could be much more significant, but they have not yet been quantified. However, even at $500,000 per plant the total costs for 59 plants would only be about $30 million. This is not a lot if the province as a whole is considered, but it could be a burden for individual municipalities. Analysis of the engineers' reports should enable a more refined number.

Rehabilitation

Rehabilitation costs are normally paid out of current revenues. Revenue fund expenditure in 1997 was $910 million (table 1-3), of which $367.3 million was capital-related: $77.6 million debt and $289.8 million "transfers to own funds" (i.e., used for capital). It could be argued, however, that none of the capital-related funds should be available for growth (see next item). A conservative approach would be to assume that only the $289.8 million transferred funds are used for rehabilitation. This would indicate that sufficient funds are being applied now to meet the CWWA estimate of $172.6 million annually. They fall well short of the Powell estimate of $764 million, only covering about 40%. To meet this level, budgets and revenues would have to be increased by $465 million, or 51%. If only user rates were used, they would have to increase by about 60%. Thus, a more accurate assessment of rehabilitation costs is needed before the impact can be estimated with any confidence.

Growth Cost Recovery from New Customers

Ontario legislation provides for recovery of costs expended on new infrastructure needed to satisfy system expansion:

- Servicing on private property is the responsibility of each customer.

- Customers pay service connection pipe costs from watermains to the street line. If developers build the connectors, the cost is passed on to customers in the property cost. If the municipality builds them, the cost is recovered by means of connection charges.

- Local mains fronting customer property can also be charged to abutting customers (trunk main capacity cost is not included here). If developers build the local mains, the cost is passed on to customers in the property cost. If the municipality builds them, the cost is recovered by means of frontage charges.

- The water utility normally builds major facilities. Development charges can be levied against new development to recover development-related costs.

Thus, mechanisms are available to recover the cost of facilities for new development. Developers commonly construct local facilities and recover costs in the price of the property. These costs do not show up in municipal accounts. Municipal local-servicing costs are also commonly recovered. Development charges are common, but not all municipalities apply them. They are also applied more frequently to residential consumers than to non-residential consumers.

Unfortunately, financial information returns do not show a breakdown of municipal financing sources for the water and wastewater capital funds.

Growth-related costs that appear in the capital funds should be largely offset by capital recovery mechanisms. The impact on the revenue fund and user rates should be minor. Also, the additional user revenues from growth should more than offset any growth-related capital costs that do get passed on to the revenue fund.

Further Refinement of Cost Estimates

It is critical that investments in system rehabilitation be a normal part of water system expenditures. To determine whether current levels are sufficient or what the levels should be, more detailed information on water systems is needed. In the case of above-ground facilities, the MOE has traditionally been well informed, and the current reviews of every water supply facility in the province should provide a good view of current deficiencies and ongoing rehabilitation needs. In the case of below-ground facilities, a much better inventory of items such as length, size, construction material, age, and condition is necessary to derive meaningful estimates of future rehabilitation needs.

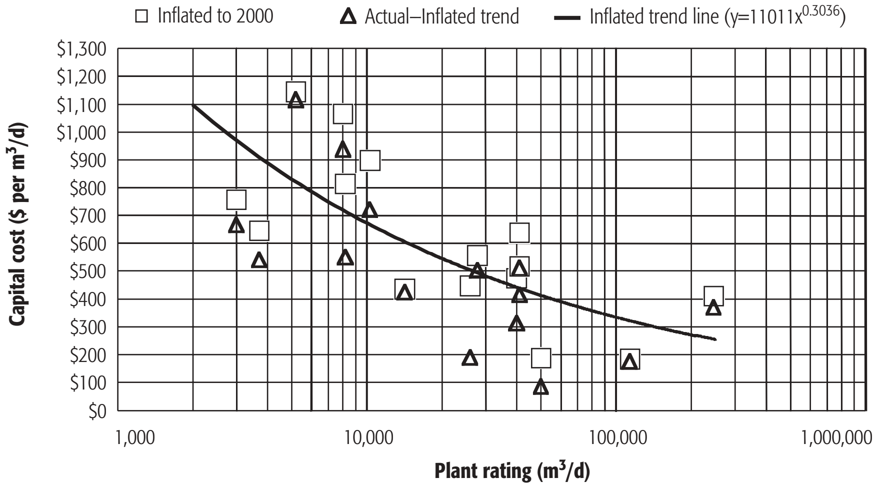
Depreciation

There is some confusion with the term 'depreciation.' It often seems to be used to reflect how much must be invested to replace deteriorating infrastructure. In utility financial reporting, however, it refers to the spreading of capital costs over the life of the item. The term is not applicable in the cash accounting method used by municipalities in Ontario. In any case, depreciation is not sufficient to generate the funds required to replace aging equipment because costs of replacement are frequently higher than the original costs being depreciated.

Regional Systems

The suggestion that small municipalities should move toward area-supply schemes may have technical advantages, but this approach should not be assumed to be cheaper. The unit cost analysis indicates that there are economies of scale, but they are most pronounced for large municipalities. The smaller municipalities do not show economies of scale.

Figure 1-22 Estimated Capital Cost for Canadian Water Treatment Plants, by Rated Capacity



1.11 Treatment Plant Cost versus Size

figure 1-22 presents an estimate of the relationship between capital cost and plant size (rated capacity), based on capital costs (adjusted for inflation) for Canadian water treatment plants constructed within the last thirty years. The information was obtained through personal communication with both water utilities and engineering consultants.

Gross Cost Estimates Based on SWIP Database

Opinions vary as to what constitutes or produces a safe drinking water supply. Nevertheless, *Ontario Drinking Water Standards* (ODWS) states that to ensure good quality supply, the minimum level of treatment for water should be

- chemically assisted filtration and disinfection for surface water sources, and
- disinfection for groundwater sources.

Examination of the latest available version of the SWIP database reveals that approximately 20 water supplies serving populations greater than 500 reported having no disinfection system in place. These were all plants abstracting groundwater from one to five wells. Allowing an estimate of $20,000 per well to install hypochlorination suggests that provision of disinfection would cost in the order of $2 million. This estimate does not allow for additional contact time that may be required to meet the new Ontario disinfection standards.

Approximately 40 water suppliers reported using surface water without filtration and approximately half of these served populations of more than 1,000 people. Applying capital cost estimates based on population suggests that chemically aided filtration for these supplies would total approximately $50 million.

It is recognized that costs will be associated with other elements of water treatment plant modernization. However, it is likely that immediate costs required to bring remaining communities into compliance with ODWS minimum treatments should be significantly less than has been previously thought.

2 Standards, Guidelines, and Objectives

2.1 Guidelines for Canadian Drinking Water Quality

The Federal-Provincial Subcommittee on Drinking Water prepares *Guidelines for Canadian Drinking Water Quality (Guidelines)*, which is published by Health Canada.[24] Representatives from Health Canada, Environment Canada, and each of the provinces and territories sit on the subcommittee, which meets twice a year to review technical documents relating to guidelines. Health Canada generally prepares these documents. The subcommittee also maintains a priority list of substances under consideration for future versions of *Guidelines*. When a new parameter reaches the stage of draft guideline, the subcommittee may circulate it for public comment. The Health Canada Web site lists parameters for which the subcommittee is currently eliciting comment.[25]

Guidelines considers substances "that have been found in drinking water and are known, or suspected to be harmful" and presents maximum acceptable concentrations (MAC) for these substances, which fall under three headings: microbiological, chemical and physical, and radiological. Health Canada notes that guidelines are in place for more than 85 physical and chemical parameters, in addition to microbiological and radiological contaminants. Although the sixth edition (1996) of *Guidelines* is the latest produced by Health Canada, revisions are published after the most recent review meeting of the subcommittee. Health Canada makes the latest available in summary form on its Web site.[26]

In Canada, water quality is the responsibility of provincial governments; the guidelines are therefore not legally enforceable. They may, however, be applied in areas of federal jurisdiction such as military bases or Indian reserves. The guidelines do form a basis for local standards enforced in several provinces. To date B.C., Alberta, Ontario, and Quebec have incorporated elements of the federal guidelines into provincial regulations.

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[24] Canada, Health Canada, 1996, *Guidelines for Canadian Drinking Water*, 6th ed. (Ottawa: Supply and Services Canada).

[25] Drinking Water Substances Priority List (October 2000) <www.hc-gs.gc.ca/ehp/bch/water_quality/priority_lst.htm>.

[26] Canada, Health Canada, 1999, *Summary of Guidelines for Canadian Drinking Water Quality* [online], [cited July 2001], <www.hc-sc.gc.ca/ehp/ehd/catalogue/bch_pubs/summary.pdf>. The latest update at the time of writing was March 2001 (tables 2–1 and 2–2 reflect these latest values).

2.1.1 Guidelines for Microbiological Parameters

Health Canada notes that of the pathogens commonly found in polluted surface water – protozoa, bacteria, and enteric viruses – only enteric viruses and bacteria are found in contaminated groundwater.[27] These pathogens are commonly responsible for gastrointestinal sickness or diarrhea. The risk of disease from water contaminated with pathogens depends on several factors, including

- pathogen concentration in water,
- the dose that is infectious to humans,
- the virulence of the pathogen and the ability of the infected person to resist it, and
- the volume of contaminated water consumed.[28]

In deriving the guideline values for microbiological quality, Health Canada observes that there is no acceptable lower limit on waterborne pathogen concentration, since some people can become ill after ingestion of no more than a single organism. Therefore, the MAC is zero. In common with most microbiological standards and guidelines for drinking water quality worldwide, *Guidelines* relies on measurement of indicator micro-organisms to warn against pathogenic contamination.

The chosen indicators are total coliforms and *Escherichia coli* or thermotolerant coliforms. Health Canada notes that, since coliforms are not a good indicator for other pathogens, absence of the bacteria does not guarantee absence of viruses or protozoa. Since it may be neither practical nor possible to test for all potential pathogens, *Guidelines* notes that effective filtration, disinfection, and an adequate disinfectant residual in the distribution system provide the best overall protection. If possible, a watershed protection program should also be adopted to help reduce the microbiological burden on the water treatment facility. *Guidelines* also recommends that authorities responsible for water safety have policies in place for issuing and rescinding boil-water orders, and that they have a contingency plan in place to deal with a waterborne disease outbreak.

Guidelines states that the MAC for coliforms should be zero organisms detectable per 100 mL. However, it also notes that because of variation in enumeration

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[27] Canada, Health Canada, 1995, *Approach to the Derivation of Drinking Water Guidelines* [online], [cited December 2000], <www.hc-sc.gc.ca/ehp/ehd/catalogue/bch_pubs/dwgsup_doc/part-1.pdf>.
[28] Ibid.

and non-uniform distribution in drinking water the following conditions are sufficient to meet the guidelines for microbiological quality of drinking water:

- No sample should contain more than 10 total coliform organisms per 100 mL, none of which should be *Escherichia coli* or thermotolerant coliforms.

- No consecutive sample from the same site should show the presence of coliform organisms.

- For community drinking water supplies,
  – not more than one sample from a set of samples taken from the community on a given day should show the presence of coliform organisms; and
  – not more than 10% of the samples based on a minimum of 10 samples should show the presence of coliform organisms.

Water should be resampled if a single sample contains up to 10 coliforms per 100 mL, or if it contains either more than 500 heterotrophic plant count colonies per mL or more than 200 background colonies on a total-coliform membrane filter.[29]

2.1.2 Guidelines for Chemical and Physical Parameters

Guidelines places values for chemical and physical parameters into three categories: maximum acceptable concentration (MAC), interim maximum acceptable concentration (IMAC), and aesthetic objective (AO). MACs must be achievable by normal treatment processes and measurable by existing analytical methods. If the MAC of a substance is too low to be achieved by normal treatment or is too low to be measured by existing analytical methods, *Guidelines* assigns the parameter an IMAC. It also recommends improvements in treatment and measurement techniques for the substance. Aesthetic objectives are assigned to substances that exhibit aesthetically displeasing qualities at concentrations lower than their MACs. Health Canada bases AO values on taste and odour threshold numbers available from the literature.[30] In most cases the AO values are much lower than the corresponding MACs.

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[29] Canada, Health Canada, 1999.
[30] Canada, Health Canada, 1995.

Guidelines MACs for the chemical and physical parameters are derived from the tolerable daily intake (TDI) of the substance based on consumption of 1.5 litres of water per day by an adult weighing 70 kilograms. In deriving the final MAC, Health Canada applies safety factors to the TDI, which make allowance for ingestion or exposure by other means. Additional safety factors are also applied. The MAC values for confirmed carcinogenic compounds are set as close to zero as "reasonably practicable."[31] This practice follows the principles relating to treatment and measurement of these contaminants.

Table 2-1 shows the values reported in *Guidelines* for chemical and physical parameters. There are some parameters for which no value is set. Health Canada posts supporting documentation for each of these parameters on its Web site. The documentation gives expansive discussion and information on each chemical and physical substance in the guidelines.

2.1.3 Guidelines for Radiological Parameters

Guidelines sets parameter values for a primary and secondary list of radionuclides (see table 2-2). Primary radionuclides should be monitored in water samples; secondary radionuclides may be monitored as required through additional screening. In setting guidelines for radionuclides, Health Canada notes that exposure through drinking water will amount to only a fraction of total exposure to radioactivity, most of which originates from natural background levels and other sources.

2.1.4 Sampling

The 1996 *Guidelines* recommends a minimum number of samples to be taken and analyzed, based on the population served by a drinking water facility (see table 2-3).

[31] Ibid.

Table 2-1 Guidelines for Canadian Drinking Water Quality – Chemical and Physical Parameters

Parameter	MAC (mg/L)	IMAC (mg/L)	AO (mg/L)
Aldicarb	0.009		
Aldrin + dieldrin	0.0007		
Aluminum[a]			
Antimony		0.006[b]	
Arsenic		0.025	
Atrazine + metabolites		0.005	
Azinphos-methyl	0.02		
Barium	1.0		
Bendiocarb	0.04		
Benzene	0.005		
Benzo[a]pyrene	0.00001		
Boron		5	
Bromate		0.01	
Bromoxynil		0.005	
Cadmium	0.005		
Carbaryl	0.09		
Carbofuran	0.09		
Carbon tetrachloride	0.005		
Chloramines (total)	3.0		
Chloride			250
Chlorpyrifos	0.09		
Chromium	0.05		
Colour			15 TCU[c]
Copper[b]			1.0
Cyanazine			

Table 2-1 Guidelines for Canadian Drinking Water Quality – Chemical and Physical Parameters, cont’d

Parameter	MAC (mg/L)	IMAC (mg/L)	AO (mg/L)
Cyanide	0.2		
Diazinon	0.02		
Dicamba	0.12		
Dichlorobenzene, 1,2-[d]	0.20		0.003
Dichlorobenzene, 1,4-[d]	0.005		0.001
Dichloroethane, 1,2-		0.005	
Dichloroethylene, 1,1-	0.014		
Dichloromethane	0.05		
Dichlorophenol, 2,4-	0.9		0.0003
Dichlorophenoxyacetic acid, 2,4- (2,4-D)		0.1	
Diclofop-methyl	0.009		
Dimethoate		0.02	
Dinoseb	0.01		
Diquat	0.07		
Diuron	0.15		
Ethylbenzene			0.0024
Fluoride[e]	1.5		
Glyphosate		0.28	
Iron			0.3
Lead[b]	0.010		
Malathion	0.19		
Manganese			0.05
Mercury	0.001		
Methoxychlor	0.9		
Metolachlor		0.05	

Table 2-1 Guidelines for Canadian Drinking Water Quality – Chemical and Physical Parameters, cont'd

Parameter	MAC (mg/L)	IMAC (mg/L)	AO (mg/L)
Metribuzin	0.08		
Monochloro-benzene	0.08		0.03
Nitrate [f]	45		
Nitrilotriacetic acid (NTA)	0.4		
Odour			inoffensive
Paraquat (as dichloride)		0.01 [g]	
Parathion	0.05		
Pentachloro-phenol	0.06		0.030
pH			6.5–8.5 [h]
Phorate	0.002		
Picloram		0.19	
Selenium	0.01		
Simazine		0.01	
Sodium [i]			200
Sulphate [j]			500
Sulphide (as H_2S)			0.05
Taste			inoffensive
Temperature			≤15°C
Terbufos		0.001	
Tetrachloro-ethylene	0.03		
Tetrachloro-phenol, 2,3,4,6-	0.1		0.0001
Toluene			0.024
Total dissolved solids (TDS)			500
Trichloroethylene	0.05		
Trichlorophenol, 2,4,6-	0.005		0.002

Table 2-1 Guidelines for Canadian Drinking Water Quality – Chemical and Physical Parameters, cont'd

Parameter	MAC (mg/L)	IMAC (mg/L)	AO (mg/L)
Trifluralin		0.045	
Trihalomethanes (total) [k]		0.1	
Turbidity	1 NTU [l]		5 NTU [l, m]
Uranium	0.1	0.02	
Vinyl chloride	0.002		
Xylenes (total)			0.3
Zinc [b]			5.0

Source: *Summary of Guidelines for Canadian Drinking Water Quality* (Canada, Health Canada, 1999)
Notes: MAC = maximum acceptable concentration; IMAC = interim maximum acceptable concentration; AO = aesthetic objective; data current to March 2001.

[a] A health-based guideline for aluminum in drinking water has not been established. However, water treatment plants using aluminum-based coagulants should optimize their operations to reduce residual aluminum levels in treated water to the lowest extent possible as a precautionary measure. Operational guidance values of less than 100 µg/L total aluminum for conventional treatment plants and less than 200 µg/L total aluminum for other types of treatment systems are recommended. Any attempt to minimize aluminum residuals must not compromise the effectiveness of disinfection processes or interfere with the removal of disinfection by-product precursors.

[b] Because first-drawn water may contain higher concentrations of metals than are found in running water after flushing, faucets should be thoroughly flushed before water is taken for consumption or analysis.

[c] TCU = true colour unit.

[d] In cases where total dichlorobenzenes are measured and concentrations exceed the most stringent value (0.005 mg/L), the concentrations of the individual isomers should be established.

[e] It is recommended, however, that the concentration of fluoride be adjusted to 0.8–1.0 mg/L, which is the optimum range for the control of dental caries.

[f] Equivalent to 10 mg/L as nitrate–nitrogen. Where nitrate and nitrite are determined separately, levels of nitrite should not exceed 3.2 mg/L.

[g] Equivalent to 0.007 mg/L for paraquat ion.

[h] No units.

[i] It is recommended that sodium be included in routine monitoring programmes, as levels may be of interest to authorities who wish to prescribe sodium-restricted diets for their patients. There may be a laxative effect in some individuals when sulphate levels exceed 500 mg/L.

[j] There may be a laxative effect in some individuals when sulphate levels exceed 500 mg/L.

[k] The IMAC for trihalomethanes is expressed as a running annual average. It is based on the risk associated with chloroform, the trihalomethane most often present and in greatest concentration in drinking water. The guideline is designated as interim until such time as the risks from other disinfection by-products are ascertained. The preferred method of controlling disinfection by-products is precursor removal; however, any method of control employed must not compromise the effectiveness of water disinfection.

[l] NTU = nephelometric turbidity unit.

[m] At the point of consumption.

Table 2-2 Guidelines for Canadian Drinking Water Quality – Radionuclides

Primary list of radionuclides

Radionuclide	MAC (Bq/L)
Natural radionuclides	
Lead-210	0.1
Radium-224	2
Radium-226	0.6
Radium-228	0.5
Thorium-228	2
Thorium-230	0.4
Thorium-232	0.1
Thorium-234	20
Uranium-234	4
Uranium-235	4
Uranium-238	4
Artificial Radionuclides	
Cesium-134	7
Cesium-137	10
Iodine-125	10
Iodine-131	6
Molybdenum-99	70
Strontium-90	5
Tritium	7,000

Secondary list of radionuclides

Radionuclide	MAC (Bq/L)
Artificial Radionuclides	
Antimony-125	100
Cerium-141	100
Cerium-144	20
Cobalt-60	2
Iron-59	40
Manganese-54	200
Niobium-95	200
Ruthenium-103	100
Ruthenium-106	10
Zinc-65	40
Zirconium-95	100

Source: Canada, Health Canada, 1999.
Bq/L = bequerels per litre

Table 2-3 Recommended Minimum Monthly Sampling

Population served	Minimum samples per month
<5,000	4
5,000–90,000	1 per 1,000
>90,000	90 plus 1 per 10,000

Source: Canada, Health Canada, 1996.

2.2 Ontario Water Resources Act

The *Ontario Water Resources Act* (*OWRA*) addresses most aspects of water protection, abstraction, treatment, and control in the province. Its provisions have spawned regulations that govern

- water works construction and classification,
- operator and analyst licensing, certification, and training,
- operating standards,
- water quality standards,
- fees and fee payment,
- use and protection of water from any source,
- all aspects of well construction and operation,
- aspects of sewage works, treatment, and discharge, and
- other miscellaneous water-related matters.

The *OWRA* applies generally to all municipalities or utilities that wish to abstract more than 50,000 litres of water per day from either surface or groundwater sources. The act outlines the requirements for licensing to abstract water and the procedure that must be followed to construct works to abstract, treat, or distribute water. It also outlines the administration of the act, including the responsibilities of the minister of the environment, directors, and provincial officers. Penalties for violating the provisions of the *OWRA* include fines of up to $200,000 per day and imprisonment. Detailed examination of the provisions of the *OWRA* and its daughter regulation is beyond the scope of this paper. However, the major elements that control drinking water quality and safety are examined in the following sections.

2.3 Ontario Drinking Water Protection Regulation

In August 2000 the government of Ontario amended the *Ontario Water Resources Act* to include the Ontario Drinking Water Protection Regulation (ODWPR).[32] The regulation was fashioned to strengthen the provincial government's ability to oversee drinking water supply in Ontario and to detail the responsibilities of water suppliers, laboratories, and regulators in keeping water safe for human consumption. It also made the Ontario Drinking Water Standards enforceable by law.

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[32] Ontario, Ministry of the Environment, 2000a, *Drinking Water Protection* [online], Ontario Regulation 459/00, [cited December 2000], <www.ene.gov.on.ca/envision/WaterReg/Reg-final.pdf>.

2.3.1 Applicability

The provisions of the ODWPR apply to new and existing water supplies. The regulation applies to water systems that supply more than 50 m^3/d or are capable of providing greater than 250 m^3/d, or that serve more than five private residences. It does not apply to systems that receive all their water from another supply system unless (1) they are owned or operated either by a municipality or by the Ontario Clean Water Agency (OCWA), (2) they re-supply water to OCWA or a municipality, or (3) they disinfect or treat the water.

2.3.2 Minimum Treatment Requirements for Drinking Water

The ODWPR defines minimum treatment requirements for Ontario water supplies. By December 31, 2002, no water, unless exempted by the MOE, can be supplied to a distribution system or to plumbing unless it has been disinfected or subjected to an equivalent treatment. Owners or operators of water supplies that use surface water sources must in all cases use at least chemically assisted filtration (i.e., they must add chemicals that agglomerate particles in the water) and disinfection, or an equivalent treatment. The regulation allows no exceptions to this requirement. The minimum required treatment for groundwater sources is disinfection; however, under certain circumstances the regulation allows operators or owners to supply non-disinfected water. These circumstances apply only to water obtained exclusively from a groundwater source and where the following conditions are met:

- The municipal council agrees, if the municipality is the owner.
- The local medical officer of health gives consent in writing.
- All samples taken in the previous 24 months meet the requirements of the regulation.
- A hydrogeologist's report assures the good condition of the aquifer, wells, and wellhead protection.
- The impacts of existing and future land use do not adversely affect the system.
- Consumers have been given adequate notice of a public meeting held to allow their input.
- A summary of the comments and responses made at this meeting is provided.
- Standby disinfection equipment and chemicals are available and maintained for immediate use if required.

2.3.3 Sampling, Analysis, and Notification

The ODWPR requires frequent sampling – both in the distribution system and at the plant discharge – for microbiological parameters, turbidity, chlorine residual, fluoride, volatile organics, inorganics, and other parameters considered potentially threatening to health. The regulation specifies both the parameters that must be tested and the testing frequency. Raw water and plant discharge must be sampled at least weekly for microbiological parameters; the number of samples required from the distribution system varies according to the number of people served. The regulation also varies the number of samples required for disinfectant residual testing, based on the number of people supplied. Table 2-4 reproduces the sampling frequency shown in the ODWPR for water supply samples.

Only an accredited laboratory may analyze water samples for health-related parameters, and water supply operators may send samples only to laboratories approved by the Ministry of the Environment. An owner or operator of a water supply who chooses to change laboratories is required to inform the MOE of this change. This requirement allows the MOE to make the new laboratory aware of its obligations under the provisions of the ODWPR.

The regulation also specifies action to be taken if a sample exceeds the *Ontario Drinking Water Standards* MAC or IMAC for health-related parameters or if the sample shows adverse water quality. Such adverse water quality conditions include

- presence of *E. coli* or total coliforms in distributed water samples,
- high counts in background colony testing,
- no disinfectant residual in distributed water,
- presence of micro-organisms noted in the ODWPR other than *E. coli* or coliforms,
- sodium concentration greater than 20 mg/L, and
- presence of a pesticide.

Laboratory staff who discover the excess values or adverse water quality must immediately inform the MOE, the local medical health officer, and the water supplier. They must establish spoken contact with MOE and medical health staff and they must send a confirming report in writing within 24 hours. Similarly, the regulation obliges a water supplier to give notice of samples that exceed the MAC, IMAC, or adverse quality designations. The notification duties of the supplier under the regulation are the same as those for laboratory staff. The regulation outlines corrective actions the supplier must initiate if

Table 2-4 Minimum Sampling and Analysis Frequency Required by the Ontario Drinking Water Protection Regulation

Parameter	Surface water source with filtration	Surface water source without filtration	Groundwater source
Microbiological Total coliforms Escherichia coli or fecal coliforms Heterotrophic plate count or total colony count	Up to 100,000 population, a minimum of eight samples plus an additional one sample per 1,000 population shall be taken monthly in the distribution system, with at least one such sample taken every week. Over 100,000 population, a minimum of 100 samples plus an additional one sample per 10,000 population shall be taken monthly in the distribution system, with at least three such samples taken every week. Only 25 per cent of each batch of the above samples needs to be analyzed for heterotrophic plate count or background colonies on a total coliform membrane filter analysis. A sample must be taken at least once per week from the point at which treated water enters the distribution system. A sample must be taken at least once per week from the raw water source (in a groundwater source this means each well).		
Turbidity	Grab sample every 4 h or continuous monitoring on each filter effluent line For <500 persons, monitoring can be reduced to 2 grab samples per day	Continuous monitoring	Grab sample once a day
Chlorine residual (equivalent to free chlorine residual)	Continuous monitoring for >3,000 people Grab samples <3,000 people: population — frequency 500 — 1/d 500–1,000 — 2/d 1,001–2,500 — 3/d 2,501–3,000 — 4/d Distribution samples shall be taken simultaneously with and at the same location as required for micro-biological sampling		Grab sample once a day Distribution samples shall be taken simultaneously with and at the same location as required for microbiological sampling.
Fluoride	Continuous monitoring or daily monitoring using grab sampling where treatment process includes fluoridation All other supply systems shall monitor for fluoride annually.		
Volatile organics (compounds listed in DWPR, table B)	Trihalomethanes quarterly in the distribution system at a point reflecting the maximum residence time in the distribution system All others quarterly		
Inorganics (compounds listed in DWPR, table C)	Annually In addition, lead shall be sampled annually in the distribution system at a point reflecting the maximum residence time in the distribution system.		Every three years. In addition, lead shall be sampled annually in the distribution system at a point reflecting the maximum residence time.
Sodium	Not required		Every five years
Nitrates/nitrites	Quarterly		
Pesticides & PCB (compounds listed in DWPR)	Quarterly		

Source: Ontario, Ministry of the Environment, 2000a.

water quality is compromised. Actions range from additional sampling to increasing disinfectant dosing, in addition to the notification requirements.

Licensed operators may analyze samples for parameters used to help in operation of the supply system. However, the regulation obliges any operator who carries out these tests to have an operating licence, or one year's laboratory experience, or to have passed, within the previous 36 months, an examination in water quality analysis.

2.3.4 Reporting

Water suppliers must complete several different forms of reporting required by the ODWPR. The reports are designed to inform consumers of the quality of their drinking water. The supplier must make available for public inspection all of the past two years' laboratory reports, operational parameter records, MOE approvals or orders, and quarterly water quality reports, together with copies of the Ontario Drinking Water Protection Regulation and *Ontario Drinking Water Standards.* This provision does not apply to documentation completed before the regulation came into force.

Water suppliers are also required to produce quarterly reports, which must describe the water system, how it operates, and the sources used for treatment and supply. The reports must also profile the measures the supplier has taken to comply with the provisions of the regulation and the Ontario Drinking Water Standards, and they must summarize the analytical results for water quality for the previous three months. The supplier must indicate that copies of the report are available, free of charge, to consumers. A supplier who serves more than 10,000 people must post quarterly waterworks reports on an Internet Web site.

The regulation also requires suppliers to post a public warning in cases where sampling or analysis for microbiological parameters has not been completed in accordance with the regulation, or where a microbiological parameter measurement exceeds the ODWS values and corrective action has not been taken. If the supplier fails to comply with this provision, a public health inspector or a provincial officer may post the warning.

Water suppliers are required to keep all laboratory reports, operational parameter records, MOE approvals or orders, quarterly water quality reports, and engineers' reports for at least five years. All reports and records must be made available to the MOE when requested.

2.3.5 Engineer's Report

To ensure that water facilities in Ontario continue to produce safe drinking water in the future, the ODWPR requires water suppliers to commission a professional engineer to examine the supply facilities and make a report. The engineer's report, to be updated at least every three years, must include

- a description of the water supply facilities other than the distribution system;
- copies of certificates of approval for the facilities;
- an assessment of potential for microbiological contamination;
- a characterization of the raw water source to confirm treatment necessary to meet the ODWS and the regulation;
- an assessment of operational procedures, including review of the operations manual;
- an assessment of physical works and their ability to meet the requirements of the regulation, the ODWS, and the Recommended Standards for Waterworks, 1997 (also known as the "10 State Standards");[33] and
- a recommendation for a site-specific monitoring program for the facilities, including the distribution system, that specifies what parameters should be monitored, where and how often they should be monitored, and the type of sampling.

The MOE has published *Model Conditions for Certificates of Approval,* which outlines monitoring program requirements for several types of water supply facilities, including groundwater supplies with treatment, groundwater supplies with chlorination only, surface water supplies, and supplies that re-chlorinate water received from another municipality's supply system.[34]

[33] Great Lakes–Upper Mississippi River Board of State and Provincial Public Health and Environmental Managers, 1997, *Recommended Standards for Water Works*, 1997 edition (Albany, N.Y.: Health Education Services).

[34] Ontario, Ministry of the Environment, 2000c, *Model Conditions for Certificates of Approval: Groundwater Supply with Treatment,* PIBS 4060e [online], [cited July 2001], <www.ene.gov.on.ca/envision/Waterreg/Pibs4060.pdf>. Also see *Groundwater Supply with Chlorination Only,* PIBS 4059e <~Pibs4059.pdf>; *Surface Water Supply,* PIBS 4061e <~Pibs4061.pdf>; *Re-chlorination Facility Tapping Another Municipality's Water Supply System,* PIBS 4073e <~Pibs4073.pdf>.

The engineer's report must be submitted to the director of the Environmental Assessment and Approvals Branch of the MOE. The engineer who prepares the report cannot be an employee of the water supplier.

2.4 Ontario Drinking Water Standards

2.4.1 Standards, Objectives, and Guidelines

The Ontario Ministry of the Environment published *Ontario Drinking Water Standards* (ODWS) in August 2000. By moving from suggested guidelines to legally enforceable standards the Government of Ontario instituted a major policy change for water regulation in the province. Previously, the MOE had relied on site-specific operating licences to regulate treated water quality. The Ontario Drinking Water Objectives had laid out guideline values and recommendations for good practice, but they were not enforceable, except through certificates of approval or director's orders.

The primary purpose of *Standards* is "to protect public health through the provision of safe drinking water."[35] The standards focus on drinking water quality as it relates to health, aesthetics, and economics. Water quality parameters that affect health include pathogen concentration, toxic chemicals, and radioactive substances; aesthetic considerations include taste, odour, turbidity, and colour; and factors that primarily increase costs include corrosiveness, potential to form incrustations, and excessive soap consumption.

In common with the guidelines of other countries (e.g., Australia), ODWS cautions that the listed standard values represent the minimum acceptable quality level for water supply; supplies of higher quality cannot be allowed to degrade to the guideline levels. Also in common with other standards and guidelines, ODWS sets limits for microbiological, chemical, physical, and radioactive characteristics. Microbiological quality is noted as the most important element of water quality because of its disease-causing potential. ODWS does not set numerical limits for viruses or protozoa (e.g., *Giardia* or *Cryptosporidium),* but it does note that it is desirable not to have them present in drinking water. Accordingly, chlorination provisions are set to address *Giardia*

[35] Ontario, Ministry of the Environment, 2000d, *Ontario Drinking Water Standards*, PIBS 4065e [online], revised January 2001 [cited July 2001], <www.ene.gov.on.ca/envision/WaterReg/Pibs4065.pdf>.

and virus inactivation. OWDS also notes that, to provide effective protection, a water supply system should be well-managed, include chemically assisted filtration and disinfection, provide an adequate disinfectant residual in the distribution system, and follow a comprehensive monitoring program for pathogens.

ODWS proposes to control chemical concentration in drinking water. This recognizes that although the effects of chemicals in drinking water are rarely acute, they do add to overall exposure experienced though all pathways.

All water sources contain some organic parameters, albeit at a low level. Although OWDS notes that synthetic organics detected in Ontario water are present only at very low levels and so do not appear to pose a threat to health, it does state that every effort must be made to maintain pesticide-free water.

In dealing with physical characteristics, ODWS states that these parameters are primarily of aesthetic interest. Nevertheless, they can intensify the danger posed by other classes of compounds. The example is given of higher temperatures enhancing growth of pathogenic micro-organisms. Turbidity is presented as the only physical parameter with a health-related limit.

The standards include limits on concentration of radioactive substances in water. OWDS notes that there is no threshold value below which exposure is considered safe. It requires that levels be maintained as low as possible and that they should in no instance exceed the MACs presented.

Following the example of the Health Canada *Guidelines for Canadian Drinking Water Quality*, ODWS presents standard values as maximum acceptable concentrations (MAC), interim maximum acceptable concentrations (IMAC), and aesthetic objectives (AO). With only a few exceptions, the ODWS values are the same as those in *Guidelines* for physical and chemical parameters. The main difference lies in the listing of some parameters as "operational guidelines" in ODWS, a designation that does not exist in the federal guidelines. Operational guidelines (see table 2-5) are used to ensure good treatment and distribution of water. ODWS provides a more extensive list of radionuclides, and, although the microbiological parameter MACs are the same in both documents, ODWS follows a more detailed sampling frequency protocol.[36]

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[36] This protocol also appears in the Ontario drinking water protection regulation (Ontario, Ministry of the Environment, 2000a).

ODWS also covers sampling, analysis, and corrective action. However, since the points raised are essentially the same as those discussed in section 2.3.3, they will not be repeated here.

2.4.2 Water Works

ODWS goes beyond a simple listing of parameter values to be met by Ontario water supplies. It also outlines areas of good practice to be applied to protection of water sources, treatment, and operations. It states that in choosing a source, a supplier should consider water that is most likely to meet the required quality. Parameter values that continually exceed either MACs or IMACs could cause the MOE to reject the source unless the water can be effectively and economically treated. It is also noted that chemical parameters with concentrations greater than the aesthetic objectives should be cause to consider another water source, if one is available at a reasonable cost. ODWS suggests that suppliers should survey impacts of pollution on source water and keep track of potential pollution sources.

ODWS reiterates the minimum standards of treatment specified by the Drinking Water Protection Regulation. It also stresses the importance of public health and notes items that can assist in its protection, including

- appropriate treatment processes,
- adequate capacity to meet demand,
- a careful choice of design and location of facilities to minimize pollution effects and source-fluctuation problems, and

Table 2-5 Operational Guideline Parameters

Parameter	Objective (mg/L)
Alkalinity (as $CaCO_3$)	30–500
Aluminum	0.10
Hardness (as $CaCO_3$)	80–100
Organic nitrogen	0.15
pH	6.5–8.5 (pH units)

Source: Ontario, Ministry of the Environment, 2000d

- operators who hold licences in accordance with the provisions of Ontario Regulation 435/93, Water and Sewage Works, under the *Ontario Water Resources Act*.

Approval of Water Works

ODWS outlines the approval conditions for new water works or modifications to existing supplies. Approval must be obtained from the MOE in accordance with section 52 of the *OWRA*. Generally, the bases for approval are

- sufficient quantity and good quality source water,
- adequate treatment facilities,
- adequate capacity to meet demands without developing low pressure in the distribution system,
- good engineering,
- compliance with the appropriate policies and guidelines, and
- consideration of the public interest.

To demonstrate the necessary water quality, examination of sources must be completed with sufficient sampling over an appropriate time frame.

2.4.4 Responsibility for Water Quality

ODWS sets out the responsibilities associated with water supply: the municipality that distributes water is responsible for water quality, even if it contracts supply services to someone else. Owners are also required to ensure that a protocol is in place to deal with notification and corrective action. The same provisions apply to private owners and operators who are covered by the provisions of the *OWRA*.

2.4.5 Parameter Information

Appendixes to the body of the document briefly examine each of the parameters for which standards are set. This provides useful information about what form each contaminant might take and where it can come from.

2.4.6 Chlorination of Potable Water Supplies

ODWS presents a major change to the requirements for water disinfection in the province. Procedure B13-3 prescribes the requirements for chlorination of Ontario water supplies. This procedure follows closely the provisions of the U.S. Environmental Protection Agency's Surface Water Treatment Rule (SWTR).[37] Because viruses and *Giardia* cysts are relatively difficult to sample and measure, the EPA, and now Ontario, base their disinfection requirements on the high probability that a properly operated treatment plant and a disinfection process that follows the specifications of the SWTR will remove or inactivate 99.9% of *Giardia* cysts and 99.99% of viruses. Thus, the SWTR and procedure B13-3 present an indirect assurance of pathogen control. It should be noted that bacteria such as *E. coli* would be extremely unlikely to survive the conditions established to give this level of virus and cyst kill, since both of these organisms are significantly more difficult to inactivate. Note also that ODWS discusses the percentage removals as "log" removals. A 2-log removal is equivalent to 99% removal, a 3-log removal is equivalent to 99.9%, a 4-log removal is equivalent to 99.99%, and so on. The following formula allows conversion between intermediate log removals (e.g., 2.5 log) and percentages:

$$P = 100 - 10^{2-N}, \text{ where } P = \text{percentage removal and } N = \text{log removal.}$$

In establishing conditions to ensure the required removal of cysts and viruses, the SWTR and B13-3 rely on the "CT" concept. This concept may be briefly introduced by stating that for a given disinfectant the (multiplicative) product of the appropriate disinfectant concentration (in milligrams per litre) and the effective time of contact (in minutes) between the disinfectant and the micro-organism will produce a specified percentage inactivation of that micro-organism population in water. C is measured as the residual concentration in water and T is the effective time of contact. (See section 4.3.4 for more detail on the CT concept)

By listing known CT values, the ODWS allows water suppliers to calculate an appropriate chlorine dose to achieve, say, a 3-log removal of cysts once they know how long the cysts will remain in contact with the disinfectant. This

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[37] United States, Environmental Protection Agency, Office of Water, Science and Technology Branch, 1991, *Guidance Manual for Compliance with the Filtration and Disinfection Requirements for Public Water Systems Using Surface Water Sources* ([Washington]: EPA).

residence time is calculated by measuring the flow through the disinfectant contact chamber, and perhaps a reservoir, and dividing it into the volume of these tanks (tank volume in m^3 divided by flow in m^3/min gives residence time in minutes). However, because some water might move through the tank in shorter than the calculated time (a phenomenon known as short circuiting), B13-3 takes account of the shorter contact time micro-organisms in this water would have with the disinfectant. To be effective the kill must be achieved technically before it reaches the first customer, but realistically before the water leaves the tank – the first tap is usually at the treatment plant. Therefore, the time to be used in CT calculation is the T_{10}, which is the time after which 10% of water entering a vessel has left it (or perhaps more easily imagined, the time for which 90% of the water remains inside). Because the T_{10} can differ significantly from the calculated residence time, the ODWS provides factors that reduce the calculated time according to the baffling of the reservoir (i.e., the steps taken to ensure that water stays in the tank with a minimum of short circuiting). This reduced time is to be used in the CT calculation.

Because CT numbers vary with temperature, pH, disinfectant residual, and degree of inactivation required, ODWS lists them according to various combinations of these factors.

In adopting the SWTR provisions, the MOE has adopted the first regulations specifically designed to address inactivation of *Giardia* cysts and viruses under the complete range of conditions normally experienced in water treatment plants in Ontario. Note, however, that the provisions of ODWS as they stand do not directly address the presence of *Cryptosporidium* in drinking water. This protozoan pathogen can also induce illness after ingestion of low doses, and it is extremely difficult to inactivate using normal water treatment doses of chlorine. In its Enhanced Surface Water Treatment Rule, an update of the original, the EPA adopted a requirement for less than 0.3 NTU (turbidity units) in the discharge from filters to assure removal of *Cryptosporidium.* The MOE has not adopted similar provisions in ODWS. Nevertheless, many municipal treatment plants already achieve significantly lower turbidity in their treated water even though it is not stipulated. ODWS currently requires a maximum turbidity of 1.0 NTU in water entering the distribution system and no more than 5.0 NTU at the point of consumption.

3 Water Utility Best Practices

3.1 Introduction

When reviewing best practices for treating and distributing drinking water, one must examine all the elements of supply managed by a water utility. These elements include the source water, the treatment process, the water distribution system, the services provided to customers and the community, and environmental impact. Some have a more direct link than others to water quality, but all have an impact on the drinking water provided to the customers and the community.

Water utilities perform many activities to meet the drinking water needs of their customers. These activities, which vary from one provider to the next, depend on factors such as water source (surface versus groundwater, lake versus river), seasonal climatic conditions in the community (e.g., Windsor versus Timmins), topography, customer expectations, and utilities management philosophy.

Best practices continuously evolve in response to ongoing changes in water treatment technology, equipment, materials, communication methods, regulations, detection capabilities, etc. No single drinking water supplier can provide the best practices in all of its operations. Rather, the best-practice water utility has a complete, continuous improvement program to monitor, benchmark, and implement best practices.

The American Water Works Association *QualServe Program Guidelines Manual* describes a water utility as having four main operational functions:

- water operations
- business operations
- organizational operations
- customer relations

Each function is further broken down to consider the best water-utility practices. Parts 1, 2, and 3 of the QualServe manual are the primary reference materials for this chapter.[38]

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[38] American Water Works Association and Water Environmental Federation, 1998, *QualServe Program Guidance Manual,* parts 1, 2, and 3 (Denver: AWWA).

3.2 Water Operations

Water operations include all aspects of the source water, the water treatment processes, maintenance of the water facilities and associated equipment, the water distribution system, and water quality management programs.

The best practices of water operations are discussed in four sections:

- water resources
- water treatment and maintenance
- water distribution system
- water quality management

3.2.1 Water Resources

The best-in-class utility has plans and measures in place to protect existing and future water sources. The utility will make certain that these plans are an integral part of local or regional zoning, land development planning, and watershed management. The utility will also protect its sources to make certain that water quality is maintained. This requires complete cooperation among multi-jurisdictional watershed management bodies, including conservation authorities, neighbouring municipalities, and private and public landowners.

Considerations for groundwater aquifer supplies include managing withdrawal rates, limiting development in water-recharge areas, and protecting potential contamination sources. Zoning must be used to protect the aquifer, including the wellhead protection area and the water recharge zone.

The utility must determine whether existing water supply sources (groundwater or surface water) are adequate not only for the current service area but for forecast regional economic development as well. The utility must also develop demand forecasts and plan source-water development to ensure adequate supply. The utility must manage water withdrawal rates to sustain the resource. It must have a regularly updated contingency/emergency plan in place – along with a process to activate the plan when it is required – to deal with drought, flood, or contamination.

The utility must cooperate with other entities that depend on the same aquifer, groundwater recharge area, or surface water supply. Discussions with other authorities or entities must address land use within recharge areas, for both groundwater aquifers and surface water runoff. Water utilities that follow best practices will also have a water efficiency or conservation program in place to manage the resource properly. In communities where the resource has a limited supply, re-use programs are also gaining prominence as a best practice – for uses such as agricultural irrigation.

To manage the resource properly, the utility must analyze changes in household and industrial consumption patterns, especially during peak demand. Water supply and demand management strategies must account for the supply resource, peak usage, and water efficiency and conservation programs. Although conservation or water efficiency programs primarily target water customers, the utility should also have an internal review of its "unaccounted-for" water. This includes improvement plans to reduce losses and strategies to minimize unaccounted-for water.

3.2.2 Water Treatment and Maintenance

The treatment component of a water operation has various aspects: the workforce, treatment processes, operation of the treatment facilities, and maintenance of the facilities and equipment. A utility must constantly strive to improve treatment plant operation and maintenance.

The human resources development programs used to train and develop operators and maintenance personnel constitute a key component to best practices in water treatment. A best-in-class utility will have a formal operator training program to help employees become certified.

Senior management of a best-in-class utility will understand the complexities of a treatment system and the importance of investment in maintenance, repair, and retrofits. The utility will make certain its operators are appropriately trained when new equipment and new systems are being selected and put into operation.

Any change in treatment process will be tested prior to implementation. Many best-in-class water utilities track advances in new treatment technologies through the use of pilot plants on their source water. These pilot plants are used not only for new technologies and treatment processes, but also on an ongoing basis to improve or optimize existing treatment. Both small and large utilities frequently do pilot testing and research of new treatment technologies in partnership with organizations such as the AWWA (American Water Works Association), the AWWA Research Foundation, the CWWA (Canadian Water and Wastewater Association), and the NSERC (Natural Sciences and Engineering Research Council). They may also partner on other opportunities that arise on the local, provincial, or federal level, as well as through the private sector.

Any water treatment facility must have sufficient capacity to support peak load demands, in conjunction with the storage capabilities of the facility and in the community through the distribution system. The treatment capacity of the facility must be able to meet both the community's needs and future demand forecasts.

All drinking-water customers must be confident that the water they receive meets or exceeds all drinking water standards. Compliance records must always be available to regulatory agencies and water customers. A best-in-class water utility will be able to find and correct exceptions in water quality before non-compliance issues arise. The operations of both large and small water facilities run by best-in-class water utilities are computerized and automated as required for the facility. Appropriate equipment redundancy ensures reliable operation at all times. Appropriate backup systems are in place to avoid service interruptions during unplanned equipment outages. Controls are in place to deal with all microbiological quality concerns, including the presence of *Giardia* and *Cryptosporidium*.

A well-run water treatment facility will routinely measure its performance. Instrumentation logs and charts and computerized equipment and systems should assist in attaining high water quality and efficient operation of plant equipment. Depending on the size and complexity of the water facility, either continuous monitoring or routine testing, on a shift or daily basis, must follow a formal monitoring program. Consumers must be assured that all required monitoring is performed on time and that extra monitoring is done during possible upsets such as source-water changes arising from drought, flood, wet-weather flow, etc.

Maintenance of equipment must be carried out in accordance with appropriate preventive, predictive, and run-to-failure types of maintenance programs. A *predictive* maintenance program covers all major rotating equipment such as pumps, drives, motors, generators, and compressors. *Preventive* maintenance programs may operate on the basis of seasonal use, equipment run-time, weekly, monthly, quarterly or yearly periods, or quantity of flow pumped. *Run-to-failure* maintenance can include items not critical to the operation, or that are backed up by redundant equipment. These are normally pieces of equipment that can easily be repaired or replaced from stock in inventory, and for which the cost of replacement at failure makes more economic sense than ongoing maintenance.

Most best-in-class utilities have computerized maintenance management systems that track maintenance activities and provide the utility with a variety of strategies to maintain the equipment. Such systems enable a utility to plan an appropriate maintenance frequency and monitor the effectiveness of its maintenance activities, as they relate to the workforce and to specific pieces of equipment.

A best-in-class water utility will also have a formal energy management plan – for both the treatment facilities and pumping and storage within the distribution system. Energy is one of the three main financial costs in drinking water production, along with labour and chemicals supply; an aggressive program to reduce energy consumption will involve real-time control, monitoring of energy consumption, and periodic energy audits. Energy efficiency should also be a factor when selecting pumps, drive systems, lighting systems, air compressors, and other types of high-energy-consumption equipment. A best-in-class utility will explore alternative energy efficiency methods such as self-generation, cogeneration, peak load shaving, hydro power, methane generator energy, and so on. Storing water in the distribution system and at the treatment facilities allows utilities to reduce peak production during high-energy-cost periods. By drawing down reservoirs and refilling them during periods of low energy demand, the utility can benefit from lower energy costs; this benefit is in turn passed on to the customers. Storing water in reservoirs to reduce energy costs involves modelling to consider impacts on water pressure provided to customers and availability of stored water for fire protection and emergency uses.

3.2.3 Water Distribution System

The best-in-class water utility reliably provides customers with a continuous supply of potable water at adequate pressure. The fire suppression capabilities of the distribution system should provide homeowners and businesses with low fire insurance rates. The utility's senior management must understand the complexities of water distribution and the importance of investment in maintenance, repair, and retrofits. Less disruption to the buried watermain infrastructure will provide for a more reliable water system. Coordination of rehabilitation, replacement, and maintenance activities (on a watermain, valve, fire hydrant, or other water appurtenance) with other utilities not only reduces inconvenience to customers from a traffic and possible outage point of view, but also helps reduce costs. Up-to-date information on the water distribution system is critical for appropriate and timely repairs. Most best-in-class utilities now have a computerized geographic information system, which provides location, depth, pipe material, and repair records of the components of the water system directly on screen or printed on maps.

A reliable water distribution system will have reservoirs located appropriately through the system for pressure balancing, peak demands, fire protection, and emergency needs. Water mains will be looped to provide adequate pressure for daily peak and fire protection flows, as well as to reduce inconvenience to customers during planned and emergency repairs.

The quality of drinking water flowing through the distribution system must be measured on an ongoing basis. Best-in-class water utilities will have a continuous monitoring capability at reservoirs, pumping stations, and critical points throughout the water distribution system. Continuous monitoring includes not only aspects of water quality, but also pressures and flows, which are normally monitored through a SCADA (supervisory control and data acquisition) system. To understand flow, pressure, and water quality throughout the community, large and small water distribution systems alike must be modelled, which in turn allows better decision-making for rehabilitation or replacement of watermains or updating of water treatment processes.

A best-in-class water utility will also have a program to control potential cross connections within a water distribution system. Formal preventive maintenance programs will include flushing watermains and the cleaning, inspection, and exercising of watermains, valves, fire hydrants, water service lines, and water service posts. Maintenance schedules should then be adjusted to prevent premature failures. A best-in-class water utility will have a formal watermain rehabilitation and replacement program for improving water quality and maintaining the reliability of its systems. This program will be linked directly to a long-term capital and financial planning program to assure adequate funding. No-dig and trenchless technologies for rehabilitation of watermains are also common in best-in-class water utilities.

A best-in-class utility will also invest in computerized maintenance management systems and technologies to support its field maintenance operations. Bar-code technology for maintenance of valves, fire hydrant, and other appurtenances used in the water distribution system can be very efficient, as data are downloaded at the end of the day from hand-held computers used by maintenance staff. Large items, such as water reservoirs, elevated tanks, and other critical components of the water distribution system, must also receive regular maintenance.

3.2.4 Water Quality Management

Quality of drinking water is the most critical consideration of any water system. A proactive utility will always consider the impact of drinking water quality standards on the water supplied to its customers. Should there be concerns, a process will be in place to deal with them, including laboratory bench-scale analysis and pilot plant testing. A utility has to be proactive because regulatory agencies continually change water quality standards, based on health concerns, and the public wants drinking water that exceeds all provincial and federal regulations. To stay abreast of emerging issues, water utilities must form partnerships, many of which are formed with the regulators and water industry associations. Stakeholders should be consulted if a substantial treatment process adjustment is required.

A best-in-class utility also participates in water quality optimization programs to prevent or reduce taste, odour, and other aesthetic problems. The municipality will enact the necessary bylaws or water ordinances and standards to control improper activities in the water distribution system (e.g., cross-connections, which can cause back-flow into the water system). The utility will also make certain that it has a formal water quality monitoring program that covers the entire water distribution system. It might use its own laboratory for water quality analysis or contract out the job. Either way, the utility must ensure that the laboratory is current and effective in its performance, and properly staffed with certified personnel.

3.3 Business Operations

Business operations of a water utility include

- strategic planning,
- capital improvement programs,
- engineering,
- fiscal management,

- facilities management,
- information management systems, and
- purchasing and inventory management.

3.3.1 Strategic Planning

Regardless of the size of a water utility, it must plan its business. It must answer the crucial questions that deal with its long-term future, mission, functions, capital programs, financial and human resources, performance improvement strategies, and customer service. The utility's strategic plan should be based on its vision, mission, and long-range goals. The plan will address the most difficult issues facing the utility. Management and all supervisory levels of the utility must support the plan be able to articulate it clearly to their staff and customers. The plan will clearly define which groups or departments are responsible for which tasks. It will identify the resources necessary to meet the plan (people, money, etc.) and will attempt to foresee any future government regulations. The plan must be broad enough to consider social, economic, and environmental issues associated with future development in the region or community. The plan will consider available water resources, treatment, and distribution facilities and the customer base, both existing and future.

A best-in-class utility will also benchmark its business and strategic planning process with other water utilities or similar types of industries. It will invite all relevant stakeholder groups (customers, governing bodies, employees, etc.) to be involved in the strategic planning process. Employees in turn should feel a sense of ownership for the long-range plans.

3.3.2 Capital Improvement Programs

To have a best-in-class capital improvement program, a utility must have a formal process to evaluate the condition of existing utility equipment and infrastructure and to determine its replacement and rehabilitation needs. The capital improvement program must account for the utility's regulatory compliance requirements. It must be able to prioritize capital spending through criteria that consider, in addition to regular operational issues, the consequences of customer and business disruptions, social costs, and the opportunities afforded by other infrastructure and public works projects.

A capital improvement program should be forecast well in advance (five to ten years) to ensure adequate funding and stakeholder input. The program must also assess cost effectiveness of new technologies. Customers as well as other stakeholders must have the opportunity to provide input for capital planning. Best-in-class utilities will also employ value engineering and other methods to cross-check the cost effectiveness of complex capital improvement programs.

3.3.3 Engineering

All utilities, regardless of size, use engineering consulting firms to perform selected services and projects where it makes economic and operational sense. The process of identifying and selecting engineering consultants must be well documented. It is critical that this process consistently select well-qualified firms. Pre-approval of engineers or engineering firms enables a utility to proceed with immediate or emergency needs.

The utility must have the means to monitor costs and quality control, for the engineering component as well as the construction component of any capital improvement project. According to the size of the utility, appropriate management systems for the various capital improvement programs must be in place for quality control and assurance, as well as for cost effectiveness.

3.3.4 Fiscal Management

Good financial management for water utilities requires a user-pay system in which only the users of the water system pay. The two primary revenue sources are water consumption and fire protection. The latter is not common across North America, but it is gaining prominence.

The best-in-class water utility has a completely metered water system, charging all customers on the basis of water quantity used. The actual per-cubic-metre rate structure can be a flat rate, an inclining rate, or a declining rate, depending on the community and the customer base. Regardless of the structure, full cost recovery must be implemented to operate and maintain current and long-term infrastructure.

The fire protection supply charge component is used in many best-in-class water utilities to link received revenue to the infrastructure needs of various customers. For example, some businesses exert a large fire protection demand. They need very large watermains, pumping, and storage facilities for fire protection. Yet in their day-to-day activities or processes, these customers may use very little water and so will contribute minimal revenue on a consumption-based rate structure. Therefore, a fire protection charge is levied to recoup the cost of maintenance and operations of the fire protection infrastructure that supports the business.

All rates for water utilities must reflect the actual costs of the services provided, including long-term capital investments required to maintain service. A best-in-class utility will have a financial plan in place to ensure that the utility has the capital and cash it needs to meet its business plan. Most best-in-class water utilities have sound financial performance and are financially strong, commonly reflected in the ratings of various bond-rating agencies and investment groups. The utility will have certified public accountants measure its financial performance quarterly or yearly and be subject to financial audits as well as performance audits.

A best-in-class utility will seek financial advice from outside experts when needed. The utility will also regularly conduct vigorous analysis of its rate structure, revenue generation, and capital needs to ensure that the rates are sufficient and that adequate cash and capital are available. A best-in-class utility will meet its financial obligations – payroll, debt services, and payments to suppliers – on time and, as such, be recognized as an organization with which others want to do business.

A best-in-class utility will also have a successful revenue collection system with complete control over its revenues and expenses. Best-in-class publicly owned utilities make certain that utility capital expenditures and utility operating expenses are managed separately from other local government departments and authorities. They will also ensure that appropriate activity-based costing is identified for those activities that are shared at the municipal level. A key component to a best-in-class accounting system is to make certain that staff have the measurable and objective information they need for decision making.

3.3.5 Facilities Management

The term "facilities" is used to identify all infrastructure associated with the drinking water system, including water purification plants, piping, pumping stations, reservoirs, fire hydrants, elevated tanks, and watermains. The utility must maintain up-to-date real estate maps, plot plans, engineering drawings, and similar information on tangible assets. A best-in-class utility will have in place geographic information system (GIS) mapping technology to map the complete infrastructure. It must be accurate and must cover all utility properties, easements, rights of way, etc. The GIS system should be kept up to date and be accessible to all staff who operate, maintain, or plan the infrastructure.

Measures must be in place to protect the property and facilities from unauthorized entry or activity. Where appropriate, buffer zones should be established around source-water resources to protect the watershed. Property management of the facilities must be kept up to date with a complete inventory of plant and real property, as well as rights of way and easements.

Real estate and land acquisition must also be linked to future expansion plans and to customer and service area needs. The utility's long-range plan should include a formal process to identify future real estate requirements. The utility should also participate in local and regional land planning to allow it to balance protection of resources with other legitimate land uses.

3.3.6 Information Management Systems

Information management systems are a key component in increasing the productivity and competitiveness of any organization. These systems improve the quality and timeliness of information available to employees in a utility, helping them to do their jobs more efficiently and effectively. Through information technology a utility can target areas for improvement. Operation of a large water utility requires many different information management systems. They are typically computer based and can include

- billing,
- rate structure,
- water demand forecasts,
- distribution system hydraulic modelling,
- water quality tracking and analysis,

- source yield models,
- maintenance and repair development and scheduling,
- capital project management systems,
- project design systems,
- emergency management,
- payroll,
- records management,
- human resource information systems,
- financial systems,
- supervisory control and data acquisition (SCADA),
- geographic information systems (GIS),
- computerized maintenance management system (treatment plant equipment and distribution system),
- laboratory information management systems (LIMS),
- inventory and requisition/purchasing systems,
- customer inquiries tracking system, and
- a Web site.

Which systems are used will depend on the size of the utility and its needs. Although no one system can perform all these functions, some of the newer software packages do provide multiple capabilities.

Communication capability between systems is critical for an efficiently run utility. For example, the human resource, payroll, inventory, and preventive maintenance systems must be linked to provide activity-based costing information as well as to help supervisors and management understand the operation and maintenance activities within the utility.

To ensure that all these systems are up and running properly, technical support is critical. Proper operation of personal computer hardware and software is essential for employees to perform their jobs and to communicate effectively within the organization and with their customers.

3.3.7 Purchasing and Inventory Management

A best-in-class utility will solicit competitive bids for orders of all bulk chemicals, fuels, and other major equipment, materials, and supplies. The utility will authorize staff to make credit-card purchases in cases of supply gaps or emergencies.

Warehouse inventory of spare parts and supplies should be minimized, based on supplier availability, delivery time, importance of the equipment, and redundancy in the system. Blanket orders with suppliers should be in place for such items as chemicals and specific materials. A best-in-class utility will have a just-in-time chemical delivery system that minimizes the inventory of hazardous chemicals on site and saves on stocking costs.

A large utility will have its own or suppliers' warehouses distributed within its geographic area to reduce travel time for staff to pick up supplies. In certain cases, it may have materials or specialized tools or equipment delivered to the job site by suppliers or couriers, reducing maintenance and repair downtime. To make certain that parts are available for the operation and maintenance of the utility, the information management system used for purchasing and inventory must be automated so that stock and specialized items are automatically ordered, based on importance and delivery times.

3.4 Organizational Operations

Organizational operations are the functions that normally include typical human resource and corporate activities of a utility:

- leadership
- human resource management
- continuous improvement
- health and safety, and loss control management
- emergency planning and response

3.4.1 Leadership

Best practices in leadership begin with a clear mission statement that includes a strong commitment to high-quality service and continuous improvement. The utility's organizational structure must be well suited to implement its mission and to achieve its goals. The mission statement must be well communicated to all employees as well as to customers, the governance group, investors (if applicable), and all other stakeholders. Employees must have a clear understanding of the mission and, in fact, should be able to articulate how it relates directly to their job roles and responsibilities. All employees at all levels must be committed to the mission. Goals and objectives of the organization must also be clearly communicated to all employees from the top levels of management down to the working forces. These goals and objectives must be meaningful to the employees.

The utility's leadership must have an open communication process that keeps employees informed about the future direction of the utility. Managers and supervisors must be aware that communication with their employees is a major requirement of their job. Communication channels must be open among the different levels in the organization. Employees must feel comfortable discussing work-related issues with their immediate supervisors and other levels of management, including the head of the utility. The utility should have a process for responding to questions or suggestions by employees. Staff should have ample and convenient opportunities to offer input on matters that they know something about, or that even generally concern them. All levels of management must encourage employees to ask questions and to offer suggestions.

Employees must work together to ensure that things get done correctly and on time. Team problem solving is a core competency of any best-practice utility. Every member must feel essential to the team. Management and peers must ensure that there are no barriers to innovation and creativity.

Management must ensure employee recognition and establish award programs that cover both individual and team environments. In larger utilities, all employees must know who their senior managers are. This leadership group must lead by example. In many cases, this would include walking around work areas and visiting and spending a few minutes with staff to see how things are going. Supervisors and staff need the skills to deal with conflict between employees, other resources, and customer needs, and they must be offered the opportunity to improve these skills. All supervisory levels must have a clear understanding of the scope of their duties and responsibilities. This includes giving employees the responsibilities, tools, and authority to get things done.

3.4.2 Human Resource Management

Training for all levels of staff is critical in any organization. Formal training programs covering certification and education, in addition to specific job functions, are necessary. All training programs must be measured and compared to make certain that they meet the needs of the trainees. Various modes of training are available, including formal classroom training, self-study, on-the-job training, rotational assignments, technical certification, management and professional skill development programs, and active participation in professional, community, and industrial associations. Training of all staff must be encouraged and supported, both morally and financially.

Good leadership means that managers take and encourage professional development. Individual training and education plans should be developed for each employee. Management must have an understanding of the distribution of skills in its current workforce and guide these skills to the needs of the utility and the future distribution of staff. A successful utility will have plans to deal with shortfalls resulting from such things as block retirements, new skill requirements, and changing credentials or education needs.

The level of diversity in a utility depends primarily on the community served. The best-practice utility is committed to equal opportunity and equal treatment of all employees regardless of age, sex, race, religion, or other workforce diversity factors. Good leadership will engage community organizations to help work through any problems.

Appropriate salaries and wages are critical for all levels of staff of a best-practice utility. Each staff member must receive regular performance reviews – a formal written one at least once a year. Employees should also have periodic meetings with their direct supervisors. The performance review must include all training and career development requirements. Feedback on this process must be open and honest from both the supervisor and the employee. All employees should be knowledgeable about the process and the criteria used for appraising their performance.

Recruitment and retention of staff at all levels is also critical to a best-practice organization. Retraining and other transitional assistance may be required to retain or recruit the best staff possible. To meet the needs of all employees the utility must have a fair and impartial posting process for job and promotional opportunities. Salaries and benefits must be fair and comparable to those offered in similar work environments but may be different from one community to the next.

A best-in-class utility will have good workplace policies and rules that are understandable to all employees, who must also understand how policies and procedures apply to their individual job responsibilities. Policies and procedures must be updated and documented as needed. Employees must be informed and aware of the principles and applications of laws governing discrimination, sexual harassment, and disabilities. They should also be aware of all work rules for such things as drug and alcohol screening, and safety.

How management enforces the policies and rules is critical to how employees will follow them. Managers must meet regularly with labour representatives to discuss policies and work procedures. Processes should be available for discussion of any labour relations issues with staff or their bargaining units. Management and unions should have strategies in place to form partnerships or teams to develop performance and quality improvements. Issues such as privatization and competition must be discussed candidly and constructively between management, staff, and unions.

3.4.3 Continuous Improvement

Continuous improvement is a key practice of all good utilities. A best-practice utility will establish formal long-range improvement plans for water quality, operational efficiencies, operational productivity, and so on. These plans will establish realistic, prioritized goals that will be well communicated throughout the organization. Regular communication – of how goals have been reached and how the results benefit the organization and customers – is essential.

To meet its goals, a best-practice utility will have ongoing metric benchmarking and process benchmarking. Metric benchmarking can be internal or external. Internal benchmarking includes reviews within the organization (e.g., comparisons of yearly maintenance cost for a piece of equipment). External benchmarking employs external comparisons (e.g., comparison of water treatment cost with that of a comparable utility in another jurisdiction).

Process benchmarking is based on priorities set by the organization, such as water quality parameters or operations efficiency in tasks such as watermain repair. Process benchmarking also includes visits to other utilities or similar types of industry that are known to perform an activity more efficiently, in a safer manner, or with higher customer satisfaction. A best-practice utility will have procedures for reviewing a specific process that will include getting the appropriate levels of staff involved in a team approach, mapping out the activity, addressing the bottlenecks and issues, and implementing the team's suggestions. Once this process is complete, the benchmarking numbers are reviewed to see if the goals have been met. Process benchmarking by a best-practice utility will be an ongoing activity for the numerous functions that take place.

The ongoing improvement programs of a best-in-class utility promote a work environment that is conducive to change and in which employees are empowered to make decisions relating to improvement initiatives. This requires that employees be specifically trained in the applications of formal quality management and continuous improvement practices. Senior management must allocate utility resources – training, financial investments, time, staff skills, etc. – in a manner that empowers employees to achieve improvement goals.

3.4.4 Health and Safety and Loss-Control Management

Water utilities have extensive requirements for health and safety management. A formal health and safety program will include training, guidance documents, and operational procedures, all of which must be prominently posted. Employees should know exactly where to turn to find the information they need when they face a safety risk or have questions on safety. Health and safety – which must always be a high priority for management, labour, and staff – must be fully integrated into everyday work practices and procedures at all staffing levels. A best-in-class health and safety program monitors safety on the job, investigates all accidents and near misses, and reviews all findings of these investigations to ensure staff have been properly instructed and trained. A good health and safety program includes a complete loss-control program that considers not only health and safety issues, but all aspects of environmental codes.

A best-practice utility also has special programs to manage short-term disabilities of personnel and to provide assistance and physical therapy to get injured workers back to work as soon as possible and practicable.

The nature of the water facility requires that policies and procedures for entry into confined spaces must be prominent. Electrical and mechanical hazards of maintenance activities require lock-out and tag-out policies and procedures. In the water distribution system, safety requirements for trenching are also a key focus of any best-practice utility. Employees, supervisors, and managers must be aware of the Ontario Ministry of Labour's industrial and construction regulations affecting all relevant areas. All staff working with or near the chemicals being used in drinking water treatment must be aware and well trained in their use and handling.

3.4.5 Emergency Planning and Response

Even the best-run utilities need emergency response planning. A best-practice utility will have very good success in responding to emergencies with formal, documented emergency preparedness procedures and staff trained in the use of the procedures. The training will be coordinated with the local emergency response network, such as fire, police, and ambulance. Each employee must understand his or her special role in any emergency situation. Standard response procedures must be in place and followed carefully by all utility and emergency personnel.

A comprehensive emergency response plan deals with equipment breakdowns, accidents, natural disasters, catastrophes, and any other circumstance that could disrupt normal utility operations. Specific site requirements, such as spill containment for bulk hazard materials, chemicals, and fuels, must also be taken into account. Coordination with other agencies is critical for response to any type of emergency. Formal mutual-aid arrangements must be made with local or nearby emergency response organizations. When emergencies do occur, a utility and the local emergency response groups must, where possible, have a formal corrective action plan to prevent reoccurrence.

3.5 Relations and Responsibilities

Customer and government relations refer to those organizations and people that the utility must respond to. They include local, provincial, and federal government entities, drinking water organizations, and the utility's main base of residential, industrial, commercial, and institutional customers.

3.5.1 Government Relations

A forward-thinking utility will regularly and effectively interact with local, provincial, and federal government entities as well as other public and private organizations such as road authorities and natural gas, telecommunications, and sanitary and storm sewer utilities. Good relationships are required to make certain that all organizations providing services to the public understand the complexity of the issues within easements and road allowances.

Two other main organizations with which utilities must have ongoing contact are the local health authority and the local fire authority. Their emergency response plans must be linked with the water utility's emergency plans for water quality, water pressure, and fire protection concerns. Regular meetings (at least once a year) should be undertaken with the local health and fire authorities.

These community organizations, the media, and customers will regularly portray a best-in-class water utility very positively. But, because issues continue to emerge on both the health and system-reliability sides of a water system, regular meetings with primary organizations are required – even when everything is operating smoothly and as planned. The health and fire authorities should also be made aware of the ongoing plans of the utility.

The utility must also build good working relationships with the local regulators and others, including Ontario provincial regulators. And it will be aware of emerging issues within Health Canada or Environment Canada, the U.S. Environmental Protection Agency, and the World Health Organization. Many of these relationships, or handling of ongoing emerging issues, cannot be realized solely by one utility. They are normally accomplished through memberships in, and partnerships with, drinking water organizations such as the CWWA (Canadian Water and Wastewater Association) at the Canadian federal level, the AWWA (American Water Works Association) at the international level, the OWWA (Ontario Water Works Association) at the provincial level, and other associations within the province for local issues.

3.5.2 Community Relations

Depending on the size of the utility and the size of the community, various forms of community relations are necessary. A best-in-class utility will have formal programs to deal with potential odour, noise, safety, and traffic issues that might affect the community. Utilities should publish and widely distribute annual reports on all aspects of their operations. Community education programs should be available to meet the needs of both the utility and the community. Utilities should work directly with the local school board on education programs to make certain that public interest messages are understood by all age groups.

The utility must inform the public about specific issues, such as the risk associated with disinfection by-products or the recreational use of surface waters. Under specific circumstances, communication with populations that may be at risk because of specific health concerns should also take place through the health authority. Examples of such populations are immuno-compromised people who have microbiological quality concerns, or people who may have health issues associated with sodium-restricted diets if water softening is undertaken as a treatment process.

Depending on the utility and the community, formal community advisory groups could be a good way for the utility to gain an understanding of local community issues. The utility should also be prepared to respond to local media calls to interview staff on specific health or community concerns.

The utility must also be aware of existing and emergency federal, provincial, and local regulations that can affect water quality, operations, or services delivered to customers. The utility may seek professional advice on the interpretation of regulations. In many cases, associations such as the CWWA, OWWA, and AWWA monitor the provincial and federal gazettes and inform their members of opportunities to comment on upcoming issues.

The utility must also voice its opinion to the responsible government agency during the development of regulations, local ordinances, and bylaws. The utility should attempt to participate formally in rule-making – or have its industry organizations participate – to make sure its concerns, and those of its customers, are heard. The utility must also have a formal process in place to incorporate new rules and regulatory requirements into policies, procedures, and daily operating practices.

3.5.3 Business Relations

Business relations vary from one community to the next and from one utility to the next, depending on the industrial, commercial, and institutional makeup of the community. Regardless of the size or complexity of the utility and community, all businesses must be informed about scheduled infrastructure repairs, changes to water pressure, or changes to water quality that might affect them. Procedures should be in place that give business customers ample time to respond regarding any impact on their businesses.

A best-in-class utility will work with the community and business leaders to attract new businesses to the service area. Water safety, a reliable water system, and high water quality can be promoted to attract new business to a community. The development of any community relies on the utilities that provide the services to businesses and residential customers. Utilities that produce high quality water, have a reliable delivery system, and contribute to low fire insurance rates for business and residential customers, should promote their community as a prime area for development. Where appropriate, an advisory group may be formed to help guide the utility in its communication with the business community.

3.5.4 Customer Service

The customer service component of any water utility must be an essential part of its mission statement. Management must communicate the importance of customer service to all employees. Communications to staff must include all aspects of positive and negative responses from customers. Positive responses from customers should be published within the organization so that staff can share in customer appreciation.

Utility personnel must realize that serving customers is their responsibility. Customer service guidelines – which must be provided to every employee – should cover such topics as telephone etiquette, field repairs, response times, general information about the water services provided, and appropriate customer follow-up procedures. Employees should also be able to recommend customer service improvements to the organization. Employees should also know about utility operations and should know where to refer customers to obtain more specific information on utility-related topics.

Field customer personnel must be courteous and have a neat appearance. Customer satisfaction surveys and follow-up to complaints will also be used by a best-in-class utility. The follow-up should be part of a service personnel work-order system that in turn should be linked to a quality assurance system. The quality assurance system should verify that work orders have been closed and that customer inquires have been completely answered. Follow-up calls or written correspondence to customers can assure satisfaction with various utility services.

Most proactive utilities will have a customer call centre enabling customers to call one telephone number for all aspects of water services. The call centre employees or representatives should have adequate information to answer customer inquiries about billings, metering rates, water quality, taste and odour, service connection issues, watermain construction schedules, water efficiency and conservation issues, etc. Customer service representatives should also be briefed on special situations that arise within the community because of utility works. Depending on the size of the utility and the community, separate representatives may be assigned to commercial and industrial customer classes.

Investigations at the customer's residence or business can also be required in response to complaints or inquiries. Field personnel appropriate to the nature of the call must be dispatched. Field staff must also notify customers about scheduled repairs, replacements, and rehabilitation work. And they must be equipped to assist the affected customers. Depending on the nature of the work and the possible inconvenience to the customer, assistance must be available to provide an alternate supply of drinking water.

3.6 Accreditation and certification

Accreditation refers to a utility (or other organization) being officially recognized as meeting criteria set out by an authorized accreditation organization. Certification is used in many industries, with the ISO (International Organization for Standardization) program playing a large role. The following sections will discuss ISO certification and other water utility programs.

3.6.1 ISO (International Organization for Standardization)

The following information on the ISO programs is summarized from a number of sources, including the Canadian Standards Organization's *ISO 14000 Essentials*[39] and the *ISO 14001 Guidance Manual, 1998*, prepared by the National Centre for Environmental Decision-making Research.[40]

The objective of ISO is to promote development of world standards to facilitate international exchange of goods and services. There are a number of ISO series,

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[39] Canadian Standards Association, 1996, *The ISO 14000 Essentials: A Practical Guide to Implementing the ISO 14000 Standards* (Etobicoke, Ont.: CSA).
[40] R. Martin, 1998, *ISO 14001 Guidance Manual* [online], technical report NCEDR/98-06 (prepared by the National Centre for Environmental Decision-making Research) [cited July 2001], <www.ncedf.org/pdf/ISO14001.pdf>.

the more prevalent in the water treatment industry being the 9000 series and the 14000 series. The ISO 9000 series focuses on quality management system standards, which deal with customer needs. The ISO 14000 series focuses on environmental management system standards, which deal with the needs of a broad range of interested parties and the evolving needs of society for environmental protection.

ISO 14001 shares common management system principles with the ISO 9000 series, but does not deal with occupational health and safety management. As such, an organization's ISO 14001 registration process will be applicable only to aspects of environmental management systems. Following is a brief discussion of the ISO 14001 program, which is the most appropriate for the water industry.

ISO 14001

Taking into account their corporate environmental policies and objectives, best-in-class water utilities want to control the impact on the environment of their activities, products, and services. To ensure that it meets its legal and policy requirements, a utility will undertake reviews or audits to assess its environmental performance. These audits, to be effective, should be conducted within a structured management system and integrated with overall management activities. ISO 14001 is intended to provide an organization with the elements of an effective environmental management system that can be integrated with other management requirements to help the utility achieve its environmental and economic goals. The success of the system depends on the commitment from all levels and functions in an organization, especially from top management.

ISO 14001 does not establish absolute requirements for environmental performance beyond commitment to corporate policy, compliance with applicable legislation and regulations, and continuous improvement. Thus, two utilities carrying out similar activities but having different environmental performance can both comply with the ISO 14001 requirements. Adoption and implementation of a range of environmental management techniques in a systematic manner can contribute to optimal outcomes. However, the adoption of ISO 14001 standards will not in itself guarantee optimal environmental outcomes.

For a utility to achieve best-in-class environmental objectives, its environmental systems should encourage – where appropriate and economically feasible – implementation of best available technologies.

To determine compliance with ISO 14001 standards, a registrar or auditor looks for evidence that procedures have been established or implemented, that they are being maintained through periodic reviews, and that there are revisions when a review process indicates the need for them. It is the utility management's responsibility, not the auditor's, to determine the effectiveness of the procedures and systems in place.

ISO 14001 is an excellent tool that water utilities can use to review their environmental programs through a recognized process. Merely having the ISO 14001 designation does not make a utility a best-in-class organization, but having the designation is certainly considered a best practice.

3.6.2 Water Industry Accreditation Programs

The water industry has not yet developed a full, encompassing accreditation program for itself. The AWWA is currently working to develop such a program. The following information is drawn from *The AWWA Accreditation Program for Water and Wastewater Utilities*[41] and the *QualServe Program Guidance Manual.*[42]

The International Water Treatment Alliance (IWTA) is a voluntary program through which utilities adopt proven operational and administrative practices designed to improve treatment plant performance. The program has four components:

- commitment
- data collection/baseline comparison
- self-assessment/peer review
- third-party review (optional)[43]

Each of these steps is intended to assist utilities in progressing toward higher goals for finished water quality.

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[41] B. Lauer and J. Hoffbuhr, 2000, *The American Water Works Association Accreditation Program for Water and Wastewater Utilities* (AWWA technical paper) (Denver: AWWA).
[42] American Water Works Association and Water Environmental Federation, 1998
[43] International Water Treatment Alliance, 2000, *Improving Water Quality Has No Boundaries* (information flyer) (Denver: AWWA).

The IWTA was initially set up as a U.S. program, and more than 200 U.S. utilities have participated since 1995 – with proven, documented results. The international program has been piloted in Australia and in Quebec, where Reseau Environment, a water and wastewater association in Quebec, has now implemented the program. The English language international edition of the guidance program is now being completed for Canadian utilities. This program is specifically structured for water treatment plants and for continuous improvement in finished water quality.

A new water and wastewater accreditation program is currently being developed by the AWWA. Standards of best practice in all aspects of utility operation are being developed as an international application for use in this program. The intent is to have accreditation available worldwide through affiliated professional and scientific organizations. The process will require audits conducted by recognized pre-qualified international firms that specialize in this type of service.

The proposed AWWA accreditation appears to be a model that will suit the needs of regulators and utilities. The IWTA is the first component currently available to water utilities. It appears to have improved the performance of those utilities that have adopted the program in the United States. Future components of the accreditation program, when available, will have to be evaluated on their own merits.

3.6.3 Water Laboratory Accreditation

The Standards Council of Canada (SCC) was established in 1970 by Parliament under the *Standards Council of Canada Act* to promote voluntary standardization in Canada, to facilitate domestic and international trade, and to further international cooperation in relation to standards. As a part of its overall mandate, the SCC represents Canada in international standards organizations such as ISO and the International Laboratory Accreditation Cooperation (ILAC).

In 1994, SCC and the Canadian Association for Environmental Analytical Laboratories (CAEAL) entered into a partnership agreement for the accreditation of Canadian environmental testing laboratories. Under the terms of the agreement, CAEAL, a not-for-profit association, carries out assessments and operates the proficiency-testing program, which targets high-volume testing in the major disciplines of inorganic chemistry, organic chemistry, toxicology, occupational health, and microbiology. Accreditation is therefore based on satisfactory participation in an assessment program plus satisfactory participation in proficiency testing. The program is recognized internationally by ISO. It provides formal recognition of the competence of a laboratory to manage and perform specific tests or types of tests listed on its accreditation certificate.

The Canadian accreditation program was revised in 1999 to meet the latest ISO/IEC 17025 requirement. And today there is a trend for both government and private sector contracting policies to specify laboratory accreditation. Since August 2000 all Ontario laboratories performing municipal water and wastewater samples have to be accredited by SCC/CAEAL. The private laboratory performing the Walkerton water sample analyses was accredited by SCC/CAEAL.

In 1996 the Ontario Ministry of the Environment gave private laboratories the right to perform municipal water analyses. Most Ontario municipalities, being too small to justify the investment required to build and operate an accredited testing laboratory, have chosen to contract private laboratories. Nevertheless, several large Ontario regional governments operate their own laboratories.

Section 4.1.4 of CAN-P-4D, the official Canadian accreditation protocol states:

> If the laboratory is part of an organization performing activities other than testing and/or calibration, the responsibilities of key personnel in the organization that have an involvement or influence on the testing and/or calibration activities of the laboratory shall be defined in order to identify potential conflicts of interest.[44]

Furthermore, section 4.1.4, note 1, states:

> Where a laboratory is part of a larger organization, the organizational arrangements should be such that departments having conflicts of interest, such as production, commercial marketing, or finance do not adversely influence the laboratory's compliance with requirements of this International Standard.

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[44] International Organization for Standardization/International Electrotechnical Commission, 1999, *General Requirements for the Competence of Testing and Calibration Laboratories,* ISO/IEC 17025 (n.p.: IHS Inc.). This document is equivalent to the Canadian Procedural Document CAN-P-4D, which is no longer available at no charge from the Canadian Standards Council. ISO/IEC 17925 can be purchased on line from IHS, Inc. on its Global Engineering Documents Web site <global.ihs.com>.

This section is of particular interest to municipal laboratories.

3.7 Partnerships and Professional Associations

Regardless of the size of a water utility, partnerships are an essential part of being a best-in-class organization. Partnerships take various forms and include local, provincial, federal, and global components. They are formed to deal with specific or ongoing issues, and are intended to reduce costs while allowing the knowledge gained to be disseminated to all participants.

In the water industry, membership in various associations provides the participants with access to a range of information and expertise. Most regulators, municipal water utilities, private water utilities, consultants, suppliers, and many academics have memberships in some of the key water works associations, which include the AWWA (American Water Works Association), the OWWA (Ontario Water Works Association, a section of AWWA), the CWWA (Canadian Water and Wastewater Association), the OMWA (Ontario Municipal Water Association), the WEF (Water Environment Federation), and the WEAO (Water Environment Association of Ontario).

These and other associations play different roles for their membership. Many of them have written agreements among themselves to focus their mandates and reduce overlap of services to their membership. For example, agreements are in place between the AWWA and the CWWA[45] and, similarly, between the WEF and the CWWA.[46]

Another key organization, the AwwaRF (American Water Works Association Research Foundation), focuses exclusively on drinking water research and funds over US$15 million per year in this regard, allowing its members to guide research in the areas of greatest concern to them and their customers.

One of the Canadian Natural Sciences and Research Council (NSERC) chairs in water treatment is located at the University of Waterloo, and has been in existence for over seven years. The current membership includes various Ontario

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[45] American Water Works Association and Water Environmental Federation, 1998; Canadian Water and Wastewater Association and American Water Works Association, 1999, *Reciprocal Agreement for Services to Members* (Ottawa: CWWA).

[46] Canadian Water and Wastewater Association and Water Environmental Federation, 2000, *Reciprocal Agreement for Services to Members* (Ottawa: CWWA).

municipalities, the Ontario Clean Water Agency, private sector organizations (consultants and suppliers), and the University of Waterloo. The current research program focuses on drinking water quality issues and concerns as determined by the membership. The NSERC chair also trains students on drinking water issues, allowing a continuous trend of expertise to be developed and promoted in the industry.

There is a cost for membership in these associations or partnerships. The cost to a utility is often in proportion to the size of the population it serves or to the level of its decision-making authority within the membership (major partner versus minor partner). The most important aspect of a utility's being a member of an association or a partnership is the ability to be involved – to make certain that the utility is receiving appropriate service, and to help guide the group in the best interests of the public and of the organizations it represents. Best-practice utilities (large and small) join associations, partner with organizations, and disseminate the resulting information throughout their own organizations as well as to their customers and boards of directors.

The size of the partnership is irrelevant in many situations. For example, partnering a one-person organization with a utility on a communication issue can be very successful for both. Similarly, a multi-jurisdictional membership in an organization formed to deal with water quality in the Great Lakes can have tremendous benefits for the partners and could improve the long-term quality of life of anyone living within the geographic area.

Partnerships are a critical component of continuous improvement in the water industry. The leveraging of financial support for such items as research projects is most often accomplished through such partnerships. The knowledge gained through the research of a new chemical detection method, new treatment technology, new watermain rehabilitation technique, different training tool, etc., allows the partners to serve their customers more efficiently, and allows the water industry to improve continuously.