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From Source to Tap:

Guidance on the Multi-Barrier Approach to Safe Drinking Water

Produced jointly by the
Federal-Provincial-Territorial Committee on Drinking Water
and the CCME Water Quality Task Group

PN 1334

Federal-Provincial-Territorial Committee on Drinking Water

The Federal-Provincial-Territorial Committee on Drinking Water is the national body that establishes the *Guidelines for Canadian Drinking Water Quality*, published by Health Canada. These guidelines deal with microbiological, chemical and radiological contaminants found in Canadian drinking water supplies. They are recognized throughout Canada as the standard for water quality. For more information on the Committee and the *Guidelines for Canadian Drinking Water Guidelines*, see: www.hc-sc.gc.ca/waterquality

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Canadian Council of Ministers of the Environment
123 Main Street, Suite 360
Winnipeg, Manitoba R3C 1A3
Ph: (204) 948-2090
Fax: (204) 948-2125

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Preface

This document is the companion to *From Source to Tap: The Multi-Barrier Approach to Safe Drinking Water*, published in May 2002 by the Federal-Provincial-Territorial Committee on Drinking Water (CDW) of the Federal-Provincial-Territorial Committee on Environmental and Occupational Health and the Water Quality Task Group (WQTG) of the Canadian Council of Ministers of the Environment (CCME). *From Source to Tap* can be downloaded from the following websites: www.ccme.ca and www.hc-sc.gc.ca/waterquality

This document provides guidance to drinking water system owners and operators on how to apply the concept of the multi-barrier approach to Canadian drinking water supplies from source to tap. It also gives them language and tools for communicating their activities to decision-makers and consumers. In addition, the document gives decision-makers at the municipal, provincial and federal levels a structure for integrating health and environmental issues, for collaborating and sharing information, and for setting priorities. While much of the information presented is available elsewhere, this document fills a gap by bringing all the elements together in one place and presenting them to a Canadian audience.

Given the importance of drinking water quality issues, this document may be useful to anyone with an interest in the safety of Canada's drinking water supplies including regulators, system owners and operators, industry stakeholders, members of non-profit organisations and associations, academics, and members of the public. The discussions on source water protection may be of interest to an even broader audience given that this emerging area affects a diverse range of stakeholders from a variety of sectors.

The guidance contained in this document is not meant to be prescriptive and should be adapted to reflect the specific needs of a community or region. We encourage readers to consult the specific recommendations, legislation, regulations and policies of the various federal, provincial or territorial jurisdictions. None of the recommendations in the guide take precedence over any federal, provincial or territorial legislation, policy or regulation.

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1. Introduction

Serious outbreaks of waterborne disease in Canada and elsewhere have heightened public awareness that threats to water quality and quantity can have a profound impact on our health, the environment, and the economy. In order to safeguard public health, and re-instill confidence in Canada's public drinking water systems, it is imperative for drinking water supplies to be kept clean, safe and reliable. In order to do so, the components of the water supply system—the source, the treatment plant and the distribution system—must be understood and managed as a whole.

In Canada, provincial governments have the primary responsibility for managing natural resources including protecting water quality and providing and regulating drinking water services. Provinces have networks of safeguards in place to ensure the safety of drinking water, including pollution prevention programs for source water and public health guidelines or standards for drinking water quality. In addition, it is now being recognised that many goals for safe drinking water are consistent with other water quality goals, such as the protection of aquatic life.

The goal of drinking water programs is to protect public health by ensuring the safety and reliability of the drinking water supply. In order to ensure they are meeting this goal, it is important for drinking water programs and traditional safeguards to be periodically reviewed and enhanced. By implementing the multi-barrier approach from source to tap, as described in this document, Canadian drinking water supplies will have a better chance of being kept clean, safe and reliable for generations to come.

1.1 Purpose

Drinking water system owners and operators are under increased pressure from government regulators and stakeholders—including the public—to manage their systems efficiently, effectively, and in a transparent manner. This document, as the companion piece to *From Source to Tap: The Multi-Barrier Approach to Safe Drinking Water*,[1] provides guidance to these system owners and operators on how to apply the concept of the multi-barrier approach to Canadian drinking water supplies. It also gives decision-makers at the municipal, provincial and federal levels a structure for integrating health and environmental issues, for collaborating and sharing information, and for setting priorities.

The principles outlined in this document are applicable to all drinking water systems in Canada, from small communal systems in rural areas to large municipal ones in urban centres. In short, it applies to any system with a central treatment plant and distribution system. Nevertheless, small communal systems may find it difficult to implement many of the suggestions outlined in this document given their limited resources. Small system owners and operators are therefore encouraged to focus improvements in areas that promise the greatest positive impact on public health.

Individuals who draw their drinking water from sources located on their privately-owned property may also find the document useful, though not all the guidance will be relevant for such small-scale operations. For information geared specifically to their needs, owners of individual systems are encouraged to contact their provincial or territorial government department responsible for drinking water issues (either a ministry of health or environment), or Health Canada's Water Quality and Health Bureau.

Given the importance of drinking water quality issues, this document may also be useful to others with an interest in the safety of Canada's drinking water supplies: regulators, industry stakeholders, members of non-profit organisations and associations, academics, and members of the public. In addition, because source water protection is a shared responsibility between the province,

[1] *From Source to Tap: The Multi-Barrier Approach to Safe Drinking Water* was published in May 2002 by the Federal-Provincial-Territorial Committee on Drinking Water (CDW) of the Federal-Provincial-Territorial Committee on Environmental and Occupational Health and the Water Quality Task Group (WQTG) of the Canadian Council of Ministers of the Environment (CCME). It can be downloaded from the following websites: www.ccme.ca and www.hc-sc.gc.ca/waterquality

municipalities, conservation authorities, public health units, and other stakeholders, the guidance on source protection should be provided to all those who will be responsible for its implementation.

1.2 Scope of this Document

This document's primary focus is to provide guidance on how to manage drinking water systems from source to tap. Because the multi-barrier approach is not a new concept, many jurisdictions have already worked hard to incorporate some, or even all, of the elements described in this document. The document does not focus on wastewater issues or the needs of other users of water such as wildlife or livestock. While these subjects are extremely important, an in-depth discussion is beyond the scope of this document. Likewise, while protecting public health is the central theme of the document, information on health effects related to specific contaminants found in drinking water supplies is not covered as it is easily found in the *Guidelines for Canadian Drinking Water Quality* and their supporting documentation (published by Health Canada, see www.hc-sc.gc.ca/waterquality).

The guidance contained in this document is not meant to be prescriptive and should be adapted to reflect the specific needs of a community or region. Readers are encouraged to consult the specific guidance, laws, regulations and policies of the appropriate federal, provincial or territorial authority. None of the guidance in this document has precedence over federal, provincial or territorial laws, regulations and/or policies.

This document covers subjects broadly. Some concepts are only briefly summarized, especially in cases where more detailed information is readily available in reference manuals or textbooks. When more detailed information is required, references are cited in the text. In some instances, more detailed information and guidance is provided in an appendix. Wherever possible, the scientific information cited has been peer reviewed and published.

1.3 Structure of the document

The document begins with a discussion of the multi-barrier approach as a way of ensuring drinking water supplies are kept clean, safe and reliable. This approach integrates health and environmental concerns from the watershed/aquifer right through to the consumer's tap. As a risk management approach, it provides a structure for identifying hazards to the water supply which could impair the operation of the components of the water system and result in threats to public health. It also offers suggestions on how to assess the significance of these hazards and ways to manage or mitigate them. The ultimate goal is always to protect public health.

Section 3 looks at the commitments which need to be in place in order for drinking water programs to be run as effectively as possible. These commitments include legislative and policy tools, resources for research and development, financial support for infrastructure programs and staff training, as well as commitments to work with other stakeholders and the public.

Section 4 gives general information about the risk management process which leads into a discussion in Section 5 of the hazards that can compromise a drinking water system and have either a direct or indirect impact on the health of consumers.

Section 6 talks about source water protection and is divided into two sections: source water assessments and the development of watershed/aquifer management plans. Since it is not necessary (though recommended) to develop a watershed/aquifer management plan prior to designing the treatment plant, readers are given the option of moving to Section 7 after reading about source water assessments. Watershed/aquifer management plans are very important, but can be implemented at any time. Section 7 builds on the information given in Section 6 to deal with the design of drinking water treatment plants and distribution systems based on the quality of the source water.

Section 8 is entitled "Total Quality Management" and focuses on how best to manage and operate the components of the water supply once the elements are in place. This section includes discussions on monitoring, record-keeping and reporting; laboratory selection and sampling protocols; operating procedures; automated systems; facility classifications and operator training; incident and emergency response plans; program evaluations and audits; as well as abatement and enforcement programs.

The document ends with a discussion in Section 9 of public awareness and involvement in the drinking water program. Public awareness is key to the success of any drinking water program. The public needs to know how their drinking water system is managed, why disinfection is so important, and what the true financial costs are for delivering clean, safe and reliable drinking water in their communities.

References to websites and other recommended reading are given throughout the document. For ease of searching, these references have been compiled into a separate list found at the end of the document.

2. The Multi-Barrier Approach to Safe Drinking Water

2.1 Integrated Drinking Water Management

In Canada, water suppliers are committed to providing high quality drinking water at the consumer's tap. In many jurisdictions this commitment is also a legal requirement. High quality water is defined as being free of both disease-causing organisms and chemicals in concentrations that have been shown to cause health problems. Such drinking water has minimal taste and odour, making it aesthetically acceptable to the public for drinking.

> Public health considerations
>
> While treated drinking water may be used for a variety of activities beyond direct consumption—ranging from crop irrigation and livestock watering to water used as an industrial coolant—it is imperative that the public health considerations related to the quality of drinking water take precedence over the requirements of other users.

Traditionally, drinking water suppliers have relied heavily on a process called compliance monitoring to ensure water is safe to drink. Compliance monitoring relies on sampling small amounts of water in a drinking water system and testing those samples for the presence of known and quantifiable organisms or contaminants. If those samples comply with established requirements for drinking water quality, the water is considered safe to drink. However, this approach has major limitations in its sampling and monitoring techniques and in the range of factors that affect drinking water quality that can be considered. For instance, compliance monitoring only deals with microbiological pathogens and/or contaminants for which a prescribed numerical guideline value or established method of analysis has been developed, making it nearly impossible to address the entire range of potential health concerns. Sample analysis also takes time, during which period consumers will be drinking the water. If the water is contaminated, some people may become ill before the problem is identified and resolved.

In order to address these limitations, the drinking water industry has been shifting its focus in recent years to using more integrated approaches to drinking water management. For instance, the multi-barrier approach promoted in this document recognizes that the key to ensuring clean, safe, and secure drinking water is to implement multiple barriers throughout the drinking water system, from source to tap. These barriers act to block or control microbiological pathogens and chemical contaminants that may enter the water supply system, regardless of whether these substances have been identified as a concern. Under the multi-barrier approach, compliance monitoring is used as one tool for verifying that water reaching consumers is safe to drink.

As will be discussed in Section 3, sustained involvement by key stakeholders is key to the effective implementation of an integrated drinking water management system. The type and level of commitment required from each stakeholder may vary from jurisdiction to jurisdiction and area to area.

2.2 The Multi-Barrier Approach

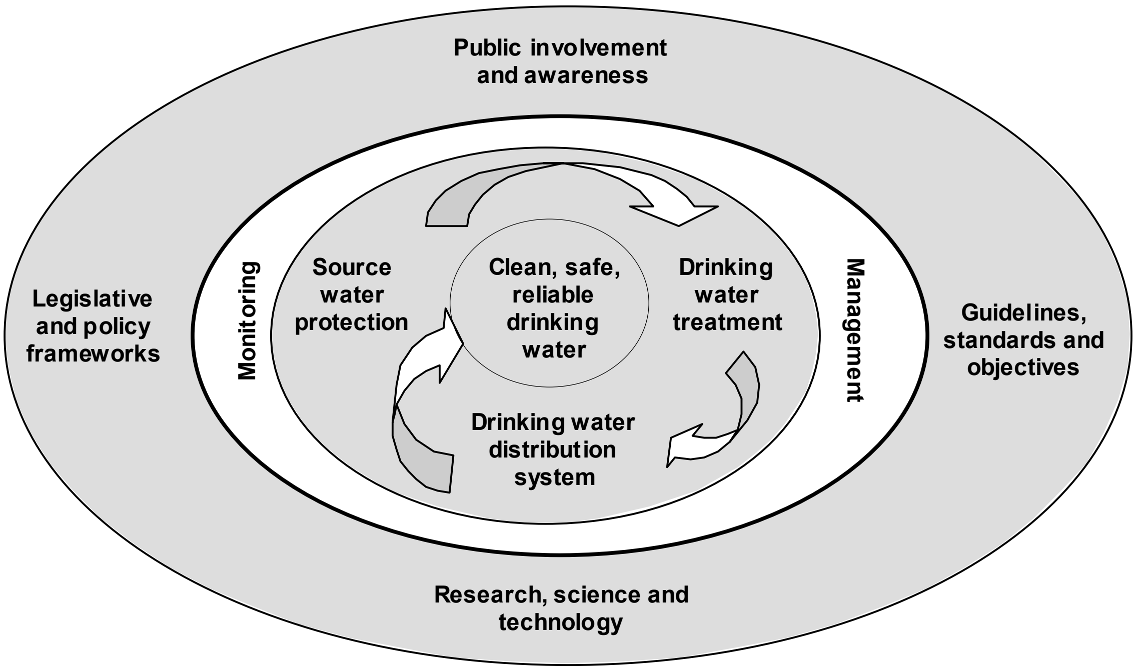
The multi-barrier approach aims to reduce the risk of drinking water contamination and to increase the feasibility and effectiveness of remedial controls or preventative options. The ultimate goal of the multi-barrier approach is to protect public health.

> The Multi-Barrier Approach is an integrated system of procedures, processes and tools that collectively prevent or reduce the contamination of drinking water from source to tap in order to reduce risks to public health.

Figure 2.1 depicts a multi-barrier approach to safe drinking water. The drinking water system contains three main elements: the source water (watershed/aquifer), the drinking water treatment plant, and the distribution system. These elements are managed in an integrated manner using procedures and tools such as:

- Water quality monitoring and management of water supplies from source to tap
- Legislative and policy frameworks
- Public involvement and awareness
- Guidelines, standards and objectives
- Research and the development of science and technology solutions

Figure 2.1: Components of the multi-barrier approach



Under the multi-barrier approach, all potential control barriers are identified along with their limitations. The barriers can be physical, such as the installation of a filtration system in a drinking water treatment plant, or they can be processes or tools that improve the overall management of a drinking water program. Examples of the latter include legislation and policies, guidelines and standards, staff training and education, and communications strategies that program staff may use to communicate with the media or the public.

The multi-barrier approach also helps ensure the long-term sustainability of water supply systems. The elements of the approach are further discussed throughout this document.

2.3 Rationale for Adopting the Multi-Barrier Approach

The benefits associated with implementing a multi-barrier approach could include better public health protection, a reduction in healthcare costs, better management of water treatment costs, and, indirectly, increased environmental protection. Specifically, benefits could include:

- Better and more consistent communication with the public leading to better public understanding of key aspects of the drinking water system and the public's role in ensuring its safety, security and reliability over the long term
- More effective communication with stakeholders stemming from the implementation of clear communication channels
- Better protected source waters stemming from increased involvement of watershed/aquifer land-use stakeholders and more opportunities for building consensus on watershed/aquifer protection strategies or approaches
- On-going education of all staff including the certification of drinking water treatment plant and distribution system operators
- Better maintained and funded treatment and distribution systems because elected officials and the public have greater awareness and understanding of the costs and benefits
- Better handled emergencies because potential hazards are understood and barriers or redundancies are in place. When incidents do take place, barriers either stop hazards from reaching consumers and/or plans are in place to remediate the problems efficiently.

These benefits are discussed in greater detail throughout the document.

The key strength of multiple barrier systems is that the limitations or failure of one or more barriers may be compensated for by the effective operation of the remaining barriers. This compensation minimizes the likelihood of contaminants passing through the entire system and being present in sufficient amounts to cause illness to consumers.

On the flipside, when drinking water systems are not well managed, poor water quality can have a serious impact on public health, resulting in both short-term (acute), and long-term (chronic) health effects. Those members of the public who are at greatest risk of developing health problems due to the microbiological quality of drinking water are the very young, the elderly, and those with suppressed immune systems (BCPHO 2001). Chronic health effects, such as cancer, can manifest themselves if people are continually exposed to some contaminants in their drinking water at levels considerably above the recommended guidelines for human health.

It is important to note that the level of exposure to contaminants found in drinking water is often much lower than exposure through other routes such as air and food.

The presence of waterborne parasites in drinking water supplies has resulted in disease outbreaks that have required medical intervention in a number of Canadian communities. The outbreak of *E-coli* in Walkerton, Ontario, resulted in the deaths of seven people and made more than 2000 other people ill. Some of those who became ill will suffer from the effects of the poisoning for their entire lives. In North Battleford, Saskatchewan, the outbreak of *Cryptosporidium* made several hundred people ill. *Cryptosporidium* in water supplies has previously caused outbreaks in Cranbrook and Kelowna, B.C., resulting in thousands of people becoming sick with gastrointestinal illness.

Poor water quality can place a significant burden on the public healthcare system, mostly from the hospitalization and care of people who become ill after consuming untreated water. For example, the Walkerton *E. coli* outbreak resulted in more than $7-million in estimated health care costs (Livernois 2002).

It is very important to also take indirect costs to public health into account. Often the number of people affected by poor water quality who do not seek hospitalization far outnumber those who do. Although no hospitalization is sought, they are nonetheless ill and consequently unable to work. Their loss of productivity can be significant.

Other financial benefits associated with implementing a multi-barrier approach may stem from source water protection activities. For instance, in some cases it may be less costly and just as effective to make improvements to a drinking water source—such as by restricting the access of wildlife or livestock to a watershed or managing other land-use activities—than it would be to install specialized treatment to control the contaminant. (It is important to note that some treatment, especially disinfection and filtration or ozonation will likely always be necessary, regardless of how closely a watershed/aquifer is managed.)

3. Commitment and Obligation

3.1 Commitment to Drinking Water

In order to be effective and to ensure drinking water supplies are kept clean, safe, and reliable, Canadian drinking water programs rely on the commitment of each participating partner to work cooperatively without losing sight of the ultimate goal of protecting public health. Partners include public or private water system owners, utility operators, elected officials, federal government departments, provincial or territorial government departments, First Nations organizations or governments, public health officials, the consuming public, service suppliers, and non-profit organisations and associations. It is important for their commitment to be based on an awareness and understanding of the importance of the drinking water program and how the decisions and actions of each participant affects water quality and therefore public health. Mindsets may need to shift from simply setting or meeting rules to evaluating existing programs, identifying deficiencies or gaps, and correcting them.

> **It is imperative that all stakeholders**—including government departments, industry, private sector companies, non-governmental organizations, and the public—**work cooperatively without losing sight of the ultimate goal: the protection of public health.**

It is important for all partners to consider formalizing their commitments and priorities related to drinking water by developing policy statements that support public health goals. It is important for the policy to state the general commitment to providing safe drinking water, meeting consumer expectations, and complying with the legal requirements of the government. In general, policy statements list the specific areas of responsibilities assumed, goals for those areas of responsibility, and guidelines on how to achieve those goals.

> The continued active involvement of decision makers, senior management, and elected officials is key to establishing and maintaining the dedication of each team member as they strive to make the drinking water program a success.

In addition to providing clarity about the roles and responsibilities of each partner, these policy statements act as a tool for promoting accountability. By establishing a water quality policy, regularly reviewing the requirements, taking action to implement the policy, and involving the participating partners—including those delivering the water quality management program—

each member demonstrates his or her commitment to the drinking water quality management program. Policy statements also provide the means for communicating with employees and with the consuming public.

A sample drinking water policy is included in Appendix A.

As key partners in the drinking water program, it is important for the actions of decision-makers to support the effective implementation and maintenance of the program. A corporate culture that promotes awareness and commitment to high quality drinking water, continuous improvement, and employee motivation is essential to the success of a drinking water program. It is very important for the participants of the drinking water program to have accountable leadership, appropriate staffing with properly trained personnel, and adequate financial resources.

Drinking water materials

All partners in the drinking water program—from regulators to system owners to the public—have a role to play in ensuring that the materials that come into contact with drinking water are safe to use and don't contaminate the water.

These materials are used throughout the drinking water system and include treatment and distribution system components (*e.g.* pipes, water mains, tanks, faucets), treatment additives (*e.g.* disinfectants, coagulants to help filtration processes), and treatment devices (*e.g.* point-of-use water filters used in the home). Organizations such as NSF International rigorously test the products on behalf of manufacturers to verify that the products are safe to use and meet manufacturers' performance claims (*e.g.* that a product removes a particular chemical contaminant or pathogen from drinking water). If products pass the testing, they are able to carry the mark of the certification body. Consumers can then look for these marks and know the product they are using is safe and lives up to the manufacturer's claims. Certification of drinking water materials includes an auditing process to ensure products continue to meet the established requirements.

3.2 Legislation and Regulation [2]

Readers are encouraged to familiarize themselves with the legislative requirements which apply in their jurisdiction prior to implementing any of the guidance contained in this document as the former are legal requirements that must be met. In some cases, the suggestions in this document go beyond provincial or territorial requirements; in others, the provincial and territorial requirements will be more stringent.

In Canada, all levels of government have some responsibility for drinking water, whether direct or indirect. Because water is considered a natural resource, the legislative responsibility for providing safe drinking water to the public generally falls under provincial or territorial jurisdiction. Each province and territory has adopted legislation to protect its water resources and to establish requirements to provide clean, safe and reliable drinking water to its citizens. The federal government is responsible for drinking water quality and quantity on federal lands and in areas that fall under federal jurisdiction, such as First Nations lands (shared responsibility), on-board common carriers (*e.g.*, ships, airplanes), and in national parks. The federal, provincial and territorial governments collaborate to develop water quality guidelines.

> Regular reviews of legislation and regulations are important to deal with emerging issues related to drinking water safety. Areas for consideration beyond the historical areas of source protection, system approval, and verification of water quality include treatment performance monitoring, data management and reporting, and operator training and certification.

All levels of government have policies and agreements in place which govern the quality of drinking water, including land-use agreements in watersheds/aquifers; water quality monitoring and inspection programs; operator certification programs; and purchasing policies for materials which come into contact with drinking water throughout the treatment and distribution chain.

The division of powers between the federal government and the provinces and territories was largely determined by the *Constitution Act* of 1867. This Act

[2] Legislation and regulations formalize the various responsibilities of governments and authorize them to oversee the provision of safe drinking water. These legal requirements form the framework to which governments' commitment is made.

allocated the ownership of surface and groundwater to the provinces as part of their control over natural resources. The territories, which have historically been federal lands, now have their own governments which have been negotiating with the federal government over the past 20 years to gain control over the natural resources, including water, within their boundaries. The provision of drinking water in all three territories is a territorial, not federal, responsibility.

The federal government works with the provinces and territories to ensure Canadians receive clean, safe, and secure drinking water. Municipalities receive their powers from the provinces and have ability to pass by-laws that can have an impact on water resources.

To address the broad range of concerns related to water uses and quality, various departments within a government are usually involved, including those responsible for natural resource management, land use planning, environmental protection, and public health. In order to ensure the success of the drinking water program, all the various activities and programs which affect drinking water need to be coordinated. This coordination may best be undertaken by a lead agency for drinking water within a jurisdiction.

Given changing priorities, it is beneficial for governments to periodically review their legislation and regulations to ensure they are still relevant and effective. All Canadian jurisdictions have undertaken such reviews since the disease outbreaks in Walkerton, Ontario, and North Battleford, Saskatchewan. That said, the recommendations made as a result of the respective inquiries may prove to be relevant in the future. It may be desirable to refer to these recommendations when conducting reviews of drinking water programs.

In addition to setting drinking water quality objectives or standards, effective drinking water regulatory programs consist of both abatement and enforcement programs. The abatement component involves working co-operatively with system owners/operators to prevent and/or solve drinking water supply or quality problems; the enforcement component involves taking appropriate action when violations of specific requirements occur. Abatement activities by a regulatory agency demonstrate a commitment to actively assist partners in ensuring the provision of safe drinking water by providing technical advice and assistance. Enforcement activities are a necessary demonstration of the importance that a regulatory agency places on the provision of safe drinking water. It indicates that non-compliance with requirements are taken seriously.

More information on abatement and enforcement programs is given in Section 8.

3.3 Jurisdictional Responsibilities

This section looks at the specific responsibilities of five key groups: the federal government, the provincial and territorial governments, municipalities, source water protection committees, and individuals. A note has been made where responsibilities overlap between jurisdictions.

3.3.1 Federal government

The federal government's responsibilities for drinking water include areas where the federal government is the water supply owner or where the water supply systems are on lands under federal control or responsibility, such as in national parks, at border crossings, or on armed forces bases. Even though constitutional responsibility for First Nations lands rests with the federal government, the responsibility for drinking water programs is divided between the First Nations Band Council, Health Canada, Indian and Northern Affairs Canada, Environment Canada, provincial governments, municipalities (where agreements are in place), and the community members. The federal government is also responsible for the quality of drinking water on board common carriers such as airplanes, trains, buses, and marine vessels. It also has some responsibilities for source waters, regulated by the *Fisheries Act*, the *Canada Water Act* and the *Canadian Environmental Protection Act*, among others.

Various federal government departments have added responsibilities that are not mandated through regulations but are, nevertheless, important to ensuring the safety of drinking water supplies. For instance, Health Canada develops the

Guidelines for Canadian Drinking Water Quality in collaboration with representatives from provincial and territorial drinking water authorities and Environment Canada. These guidelines focus on public health outcomes. The provinces and territories establish their own drinking water quality requirements using these guidelines or other more stringent ones.

Health Canada also works with standards-setting and certification organizations, industry associations and provincial and territorial authorities to promote the use of voluntary health-based performance standards for materials that come into contact with drinking water.

Health Canada also conducts research and scientific assessments related to water quality and develops drinking water information for public outreach. Information on Health Canada's research and activities in this area can be found on the Internet at: www.hc-sc.gc.ca/waterquality.

The federal government often provides financial assistance to drinking water system owners through various cost sharing arrangements such as infrastructure development programs. *More information on these programs is given in Section 3.5.2.*

Environment Canada's Federal Water Policy (1987) encourages "the use of freshwater in an efficient and equitable manner consistent with the social, economic, and environmental needs of present and future generations." The two main goals of this water policy are to:

- Protect and enhance the quality of the water resource
- Promote wise and efficient management and use of water

With these goals, more than 25 areas of responsibility are described in the policy including issues such as water use conflicts, inter-basin transfers, climate change, and fish habitat management. [3]

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[3] A new federal water policy is being drafted that maintains the importance of these goals.

Canadian Environmental Quality Guidelines, developed jointly by the federal, provincial and territorial governments, are nationally endorsed, science-based goals for the protection of aquatic ecosystems (CCME 1999a). They consist of numeric values and narrative statements for chemical, physical and biological parameters for four water quality uses: community water supplies, recreational use, aquatic life, and agricultural uses. The legislative authority for implementation of Canadian EQGs or other water quality criteria lies primarily with each provincial or territorial jurisdiction, with the exception of federal lands (CCME 1999a).

3.3.2 Provinces and Territories

Outside of the areas of federal jurisdiction noted in the previous section, regulatory oversight of drinking water quality is a provincial and territorial government responsibility. Some provincial and territorial governments reference drinking water quality criteria directly to regulations. As a result of the experiences at Walkerton and North Battleford, all provincial and territorial governments have revisited their respective drinking water programs and have made or identified improvements that ought to be made.

Most provinces and territories have established legislation and regulations for:

- Protecting water resources
- Approving the design, construction, operation, and maintenance of water treatment and distribution systems
- Establishing drinking water quality criteria
- Setting monitoring, remediation, and enforcement activities

Jurisdictions without legislation in these areas have established policies and guidelines to ensure public health is protected. Provinces and territories also make significant contributions to infrastructure programs.

In most provinces and territories, the responsibilities related to source water protection rest with departments of natural resources, environment, municipal affairs, and agriculture. Drinking water regulation or policies may involve either or both departments of public health and environment. Monitoring may be undertaken by regionalized operations staff while centralized specialists conduct proposal assessments and approvals. Provinces and territories may also legislate the creation of either a source water protection committee or a conservation authority (for more information see Section 6).

A key component of provincial and territorial drinking water programs is setting compliance and performance monitoring requirements. Compliance monitoring requirements deal with the quality of drinking water which reaches consumers while performance monitoring ensures treatment and distribution systems are functioning as designed and, ideally, at optimal levels.

Provincial and territorial responsibilities include ensuring that the appropriate legal instruments are in place to require operators to be properly trained and certified. It is important for provincial and territorial governments to commit to either generating or adopting appropriate training information for operators, regardless of whether these are private individuals or operators of complex treatment systems. *Information on operator certification is given in Section 8.6.*

Often a separate statute or regulation provides the provincial or territorial government with the authority to compel a supplier to take action during an emergency situation where drinking water safety might be compromised. There are two types of situations which can cause a water system to be compromised. The first is an event in the source water, usually out of the control of the drinking water system owner or operator. The other type of event is an operational interruption. It is important to note that provincial and territorial governments have established emergency response teams that become the lead agency when dealing with any emergency situation, including chemical or other spills in bodies of water used as a source of drinking water. *More information on these types of events and how to deal with them is given in Section 8.8.*

Requirements (other than those dealing with water quality) for some very small water systems may be different than those for municipal systems, depending on such factors as the number of people served. For instance, monitoring requirements for very small water supply systems may be less stringent or may not be included in a jurisdiction's drinking water protection regulation or program. Even though these systems typically have fewer service connections than other public systems, they do provide water to the public or a significant number of people. For this reason, it is important for provincial and territorial governments to consider the risk to public health and implement appropriate water quality control programs where they are not already in place.

3.3.3 Municipalities and non-municipal system owners

Both municipalities and non-municipal system owners are responsible for providing clean, safe and reliable drinking water to consumers.

> **Working with industry**
>
> Municipalities can work proactively with industry to initiate cleaner production programs. Less pollution going into sewers reduces the amount of treatment that has to be done at the wastewater plant, as well as improving the quality of the treated wastewater as it returns to the environment.

Municipalities are the primary providers of water services to Canadians and have made a significant investments in this area. Typically, a municipality's roles and responsibilities are defined in provincial or territorial regulations.

Municipalities can impact watersheds/aquifers through activities such as road construction and maintenance; winter control (including salting, sanding and snow removal); and waste management including the placement and management of landfills. For this reason, municipalities are encouraged to examine ways they can reduce their impacts on watersheds/aquifers. At the organizational level, this can include engaging in the development of a corporate environmental management plan such as ISO14001, EMAS, and other variations. These plans provide a consistent and transparent examination of the activities of each department and provide a management tool for identifying environmental risks and establishing priorities for action. Because municipal boundaries are not drawn along watershed/aquifer lines, municipalities also need to work with other stakeholders to protect drinking water sources. *More information on this topic is given in Section 6.*

The management and structure of waterworks systems depend on the type of ownership and legal requirements under which they are formed. With the growing recognition of the importance of water resources, it is the responsibility of management, regardless of the type of ownership, to achieve quality performance of the waterworks.

Municipal water purveyors are generally vested with the responsibility to ensure drinking water provided to consumers is safe for consumption. The utility organization has a legal and moral responsibility to its users to provide potable water which does not pose a threat to public health and is satisfactory in its physical, chemical and aesthetic characteristics. Similarly, the same obligation is required in the collection and treatment of wastewater. In this latter case the obligation relates to the protection of the environment as well as that of public health.

It is important that water utilities learn to work with other groups concerned with or who could potentially impact water related decisions, especially if systems are going to meet future challenges such as increased demands for water, cleaner water and adequate infrastructure. Stakeholder alliances are helpful in gathering information, building relationships and reaching consensus.

Working with agriculture

Agriculture plays an important role in the economic, social and political activities of many communities. While the agricultural sector brings many benefits and has made improvements in recent years, the potential for harm also exists particularly from non-point sources of pollution.

Establishing partnerships with organizations in the agricultural sector can assist in developing credibility, and gain co-operation from farmers who may be reluctant to co-operate with government (including municipal) approaches.

There is growing recognition that unilateral decisions to water quality issues no longer work and, in many cases, can result in bitter consequences when stakeholders are excluded. Many utilities have found that stakeholder alliances can be an effective forum for open dialogue with potential adversaries and could:

- Improve community relations
- Help initiate new ideas
- Help promote learning and understanding by all parties
- Help protect water rights and improve supply reliability and ability to meet demand
- Minimize liability claims
- Help develop legislative allies
- Help protect or enhance water quality

3.3.4 Individuals

The public can play an integral role in protecting the integrity of drinking water supplies. An informed, involved and supportive public forms the foundation of an effective drinking water program. The daily activities of the public (car washing, pet hygiene, etc.) in a watershed/aquifer can directly impact the quality of water that arrives at the treatment plant. Furthermore, the public is capable of exerting pressure on the governing bodies which manage the provision of drinking water.

The public has a number of responsibilities related to the success of a drinking water program, including duties to:

- Advise the government
- Comply with requests to sample water quality in their homes
- Conserve water, especially during periods of drought or when water use restrictions are in place
- Select plumbing materials (and other materials that come into contact with drinking water) for their homes that are certified as meeting health-based performance criteria
- Keep informed and participate in public fora

Without a comprehensive, well-planned effort to include the public in the development and implementation of drinking water management plans, it is unlikely that the program will be successful.

Providing additional information to owners of private drinking water systems (groundwater or surface water) is very important as these owners are responsible for regularly testing the quality of their water. Owners need to know what to do in case of microbiological or chemical contamination of their drinking water. Well-owners need to know how to maintain their wells and how to arrange to decommission wells that are no longer safe or needed. They also need to be aware of requirements for intake location and construction of a well. Provinces generally have programs in place to provide instructions for sampling private water supplies and to help interpret the laboratory results.

Mismanagement of a private water system can put the residents' and/or users' health at risk and also be a source of contamination of the groundwater aquifer or surface water. Owners are responsible for ensuring they meet any legislation or regulations in place and for having any required approvals and licenses.

More information on public involvement in, and awareness of, drinking water programs is found in Section 9.

3.4 Water Quality Guidelines

All Canadian jurisdictions have established guidelines, objectives or standards for drinking, recreational and ambient water quality within their boundaries and areas of responsibility. **Guidelines** are recommended benchmarks against which water quality can be assessed, but are not legally enforceable. These guidelines are developed at the provincial/territorial and/or the federal level. **Objectives** are site-specific values for the protection of water users (animals, plants, and humans). Objectives are based on guidelines, but incorporate site-specific modifying chemical, physical, and/or biological factors. **Standards** are legally enforceable limits for water quality, when referenced in legislation, which cannot be exceeded for the protection of human or aquatic health.

As described previously, the provincial and territorial governments are responsible for implementing the guidelines through their respective drinking water quality and public health programs. The federal government uses the guidelines as the benchmark against which the quality of drinking water supplied on federal lands and at federal facilities is measured.

3.4.1 Environmental Quality Guidelines

Environmental quality criteria are commonly used to determine the likelihood of an adverse effect on biota from exposure to a particular contaminant (the risk) by comparing ambient levels of that contaminant against a numerical benchmark.

The Canadian Council of Ministers of the Environment (CCME), comprised of the ministers of environment from all provincial, territorial and federal governments, establishes four sets of guidelines which aim to:

- Protect aquatic life by setting guidelines for water quality and sediment quality
- Ensure the quality of water used in agriculture (for livestock and irrigation)
- Protect wildlife that rely on aquatic life as a food source (tissue residue guidelines)

Provinces and territories may adopt these guidelines, or others, as they see fit. Meeting Environmental Quality Guidelines is important because we depend on our water resources for our health, recreation and our livelihoods.

For more information on these guidelines, visit the CCME's website at: www.ccme.ca

3.4.2 Guidelines for Canadian Drinking Water Quality

The *Guidelines for Canadian Drinking Water Quality* (the guidelines) are developed cooperatively by the federal, provincial and territorial governments through the Federal-Provincial-Territorial Committee on Drinking Water[4] (CDW), a standing Committee under the Federal-Provincial-Territorial Committee on Environmental and Occupational Health. As noted previously, the provinces and territories establish their drinking water quality requirements using these guidelines or other more stringent ones.

> **Drinking Water Committee**
>
> The Federal-Provincial-Territorial Committee on Drinking Water is committed to providing public access to its processes, proceedings, and decisions.
>
> Health Canada maintains Committee information on its website: www.hc-sc.gc.ca/waterquality

The guidelines are scientifically-based criteria that characterize what is considered safe, clean, reliable, and aesthetically-pleasing drinking water, regardless of whether the water is from a public, semi-public, or private supply. The development of the drinking water guidelines involves the scientific assessment of health risks, the practical assessment of the costs and potential benefits associated with meeting the

[4] Name changed from Subcommittee to Committee on Drinking Water (CDW) in 2002

guidelines, and consultation with the public, owners, and water supply service industries.

3.5 On-going Investment and Maintenance Programs

The long-term success of the drinking water program requires a commitment to adequately fund the on-going operation and maintenance of the system and pay for the inevitable capital works that will be required to upgrade or replace components (including reservoirs, dams, and intakes) as they age. This commitment also includes funding source water protection activities such as the development of watershed/aquifer management plans and improvements to watersheds. These costs are real and need to be acknowledged in the management and planning processes through, for example, depreciation reserves funded through water rates.

Ideally, each water system would be self-supporting. A self-supporting water supplier maintains sufficient revenue to meet all annual budget needs and to contribute to a reserve fund for future improvements or emergencies. It is important for system owners to commit to funding source water protection activities, maintenance and operation of existing infrastructure, and long-term infrastructure replacement and upgrading.

> **Considerations for Funding Plans**
>
> Funding plans need to consider the entire water network. Funding arrangements need to include considerations for the water storage and distribution network as well as the treatment plant. Communities are strongly encouraged to have active repair and maintenance programs as well as cross-connection control programs in place, supported by municipal by-laws.

In order to determine the true cost of producing treated water, it is important for system owners to undertake full cost accounting (FCA) of the drinking water program. FCA is a systematic approach for identifying, calculating, and reporting the actual costs of producing safe drinking water. It takes into account past and future outlays, overhead (oversight and support services) costs, and operating costs.

FCA focuses on three major types of costs that are relatively easy to determine: up-front, operating and up-coming. Up-front costs are the initial investments and expenses necessary to provide safe drinking water: source water protection plans, initial capital expenditures for the construction of the buildings, intake, treatment facility, pipelines, etc. Operating costs are the expenses associated with managing the water source, facility, and infrastructure on a daily basis. Upcoming costs include expenditures to upgrade and/or expand treatment facilities and replace and/or repair infrastructure at the end of its useful life.

3.5.1 Investing in Source Water Protection

Source water protection measures, especially in the context of a drinking water program, are generally preventative in nature. Even during the best financial times, it is difficult to commit money to these types of programs because the public is generally much more accepting of funding tangible, visible results such as road repairs. However, protecting human health is an essential pursuit of stakeholders and participating partners in the drinking water program. The absence of illness is a positive result that can be measured, demonstrated and communicated. *Information on source water protection measures is given in Section 6.*

Between 1990 and 1995, 87 watershed management projects were conducted in Ontario, with reported total project costs ranging from $30,000 to $896,000, with a median value of $150 000 (Ministry of Environment and Energy and Ministry of Natural Resources 1997).

Funding for a watershed/aquifer effort might be found in established federal, provincial, and/or territorial programs. Most small-scale watershed/aquifer groups, however, start by looking for funding locally. Local utilities, non-profit organizations, municipalities, and others have funded watershed/aquifer management actions. Depending on the amount of funding and other resources at its disposal, a committee may be required to prioritize its planning activities.[5] In doing so, it needs to consider the following:

- Available funds
- Costs/benefits of each action (return on funds to be invested)
- Time and other non-financial resources
- Ability to get the action done
- Early successes motivate more action
- Some actions rely on other actions for success

[5] The structure and functions of Source Water Protection Committees are determined by each jurisdiction and therefore vary across the country. In general, committees have little to no direct regulatory control, though they can advise regulators to act. *For more information on Source Water Protection Committees, see Section 6.2.*

Government incentive programs are another form of investment that may be attractive to governments wanting to encourage industries to prevent pollution from entering the watershed/aquifer and to promote good stewardship practices. Examples of incentives to control water quality include:

- Fees levied on actual or estimated point-source pollutant discharges to surface waters; fees are intended to defray some of the costs associated with mitigating environmental damage and act as an initial discharge deterrent
- Taxes or subsidies on receiving water quality (these would be forfeited if pollution control was inadequate)
- Liability, which makes polluters directly responsible for any impairment to water quality as a result of their actions (Coote and Gregorich. 2000)

In addition to the above, incentives can be regulatory in nature.

EXAMPLES OF AGRICULTURAL INCENTIVES FOR PROTECTING WATER RESOURCES

It is important to note that some of the incentives discussed below are regulatory requirements in other jurisdictions.

In Ontario, the Rural Water Quality Program provides financial incentives to rural landowners to establish strategies to improve surface and groundwater quality (Coote and Gregorich. 2000). Funded projects have included manure storage facilities and associated nutrient management plans, milk house washwater treatment systems, clean water diversions from manure storages, and restricted livestock access to waterways (Coote and Gregorich. 2000).

The Ontario Ministry of Agriculture and Foods' (OMAF) Healthy Future for Ontario Agriculture program encourages producers to enhance the quality and safety of food produced in the province, to increase exportations and to improve rural water quality and uses. The last objective is achieved by funding agricultural producers who invest capital in the implementation of new technologies and better management practices to preserve source water quality and reduce water usage. Alliances of producers, non-profit agricultural organizations, and rural municipalities and agencies are encouraged to participate.

The Ministry of Agriculture, Fisheries and Food of Quebec's (MAPAQ) Prime-Vert program is intended to promote and implement better management practices, to improve production systems, to preserve and protect the environment including water, and to help producers to satisfy to the new Regulation Respecting the Reduction of Pollution from Agricultural Sources, especially concerning manure management. The Prime-Vert program provides funds depending on the projects proposed.

3.5.2 Infrastructure Investment and Maintenance

In providing water services, system owners accommodate a range of consumer demands including residential, industrial, commercial, and institutional uses. All water consumers typically have a number of expectations about their water supply, including that it:

- Be available 24 hours per day
- Be free of pathogens and toxic chemicals
- Be free of objectionable tastes and odours
- Maintain adequate pressure at all times
- Maintain sufficient volume to meet demands at all times

When water supply infrastructure programs are self-funding, costs are borne by the ratepayers or service users through normal water billing. While government "special funding" for water infrastructure is occasionally available and is important, the user-pay model may better relate the true value of water to consumers. Self-sufficiency is the only guaranteed method for communities to ensure sufficient funds are available when required.

Although self-sufficiency is the ideal situation, not all owners have equal opportunity for funding major water treatment projects due to:

- The high costs of complex water treatment and monitoring technologies
- Benefits of economies of scale available to larger cities
- Reduced tax base of small communities

In Canada, regulatory efforts directed at ensuring the provision of safe drinking water by municipalities has been greatly facilitated by government financial assistance programs for municipal water supply systems. The overall objective of such programs is to ensure all municipal waterworks systems meet provincial requirements. Through financial assistance on capital costs, it is important for the programs to be structured to maintain a reasonably equitable per capita debt between municipalities for water supply work recognizing that larger municipalities enjoy "economy of scale" benefits not available to smaller communities. For information on government funding programs, check the appropriate federal or provincial government website.

Because public health needs to be protected equally regardless of the size of the community, it is important to give special consideration for additional funding support to small systems servicing rural communities. These communities have access to a much smaller municipal tax base and are therefore not able to wholly fund infrastructure works nor to contribute their share of the capital costs required by funding programs. Small system owners are encouraged to consider all possible financing solutions—as well as alternative arrangements such as joining a near-by municipal system or a regional water supply system—prior to asking other levels of government for assistance. As part of this process, it is important to recognize that some solutions may be expensive at first but may prove cost effective in the long run.

Financing small systems

Costs are generally an important factor in both the willingness and ability of a small municipality to plan, develop and operate good waterworks. A considerable disparity exists between the ability of small and large municipalities to raise the capital needed to build water supply systems.

From a regulatory standpoint, it is therefore very desirable to have financial assistance programs that either provide an incentive for small municipalities to construct good water supply systems or at least offset some of the financial concerns municipalities may have about meeting regulatory requirements. The financial assistance program should be structured to maintain a reasonably equitable per capita debt between municipalities, regardless of size. This approach recognizes that larger municipalities enjoy "economies of scale" benefits not available to smaller communities.

Costs are generally a key factor in both the willingness and ability of a municipality to plan, develop and operate a good drinking water system. From a regulatory standpoint, it is desirable to have financial assistance programs which either provide an incentive for municipalities to construct good drinking water treatment plants and distribution systems or at least help off-set some of the financial concerns municipalities may have with respect to meeting provincial requirements for water supply works.

In addition, it is important for funding bodies to give funding priority to infrastructure projects that promise the greatest positive health impact over those projects that will have minimal health effects. For instance, funding for drinking water treatment plant maintenance and upgrades that will have a positive public health impact may be given priority over other infrastructure projects.

A secondary, but no less important, investment is ensuring that installers and designers are properly qualified. It is important for system owners to commit to using certified service agents. More information on this topic is found in Section 8.6.

For detailed information on financing, investment, and setting water rates, see:

- *5th Edition of* ***Water Supply****, by Twort C. Alan, Ratnayaka D. Don and Brandt J. Malcom. Chapter two - "Organization and Financing of Public Water Supplies" (pp. 36 to 62). Publisher: Arnold and IWA Publishing, London (2000)*
- *Canadian Water and Wastewater Association materials: "Municipal Water and Wastewater Rates Primer," "Municipal Water and Wastewater Rate Manual" (2nd Edition), "Meters Made Easy: A Guide to the Economic Appraisal of Alternative Metering Investment Strategies"*

For information on maintaining and operating infrastructure, see Section 8.

3.6 Education related to the Drinking Water Program

The successful operation of any drinking water supply system—from private wells to managing large watersheds or complex treatment plants servicing large cities—depends on the skills, abilities, and knowledge of the responsible owners and employees. Although the level of knowledge required by a home owner regarding their individual well will differ from a member of a source water protection committee or a city employee operating a large plant, each needs to understand certain basic aspects of drinking water supply management.

System owners and operators should become intimately knowledgeable of the legislation which governs their business.

In addition, because of the complexity of water quality issues, and because public health is at stake, it is critical for all members of a drinking water program—whether elected officials (including municipal), regulators, scientific staff, utility operators, or others—to have appropriate levels of knowledge and understanding of the impact of their activities and decision on the quality of the water. To this end, they need access to continuing education in this field.

The provincial and territorial governments are responsible for overseeing the drinking water quality program within their jurisdictions. Changing technology, regulatory requirements, and a general need for personnel in the water works industry to remain current, requires continuing education. It is important for departmental staff to take courses to keep pace with developments in the drinking water field. As part of this education, it is important for open dialogue to be maintained between regulators, operators, and industry. Most provinces and territories now require drinking water treatment plant operators to be certified and to maintain their water works education requirements.

A robust community education program and community support helps staff and politicians tackle difficult decisions with confidence. For instance, source water protection can inspire difficult political decisions that may restrict activities and the 'right' to use land or water that people may have become used to, particularly when related to well-entrenched activities. According a high priority to source water protection may prove to be a challenge for some municipalities.

EXAMPLE OF A COMPREHENSIVE EDUCATION PROGRAM: CROSS-CONNECTION CONTROLS

Some aspects of the drinking water program may seem too complex or technical for a broad audience. For instance, most citizens, including elected officials, do not understand what a cross-connection is or the danger it represents to the public. However, the key to establishing a cross-connection control program is awareness training of the appropriate utility personnel, municipal administrators, councillors, mayor, then public education and public relations.

Internal educational seminars could focus on the basics of cross-connection, backflow, hazards, the administration (including costs) of a program, and the potential legal liabilities of not having an effective program. Public education may need to focus on the basics, how to recognize typical cross-connections, and the consumer's ultimate responsibility (in most cases) to bear the costs of any device. A pamphlet could be sent out in consumers' routine water service bill. Language for technical topics needs to be clear, concise, and free of unexplained industry jargon.

The skill sets of the people tasked with completing the cross-connection survey of building, either internal staff or contractors, are fundamentally important to the program. Some provinces have specific criteria that identifies suitably qualified people. Others may rely on third party training offered by organizations such as Canadian chapters of AWWA which offer cross-connection control surveyors certification. Regardless, it is imperative that a municipality understand the difference in skill sets and hire appropriate personnel.

More information on cross-connection controls is found in sections 7.7.5 and 8.4.2

On the water treatment and distribution side, it is critical for utility staff to be competently trained. This training is so important because of the direct impact drinking water has on a community's well being. All personnel need training matching their functionary role. It is important for this training to be planned, delivered, and documented on a continuous basis.

It is important for system owners to commit to obtaining and maintaining their own level of training. Owners are responsible for their employees and thus need to know the significance of the information provided by their employees and the ramifications of the operating decisions being made.

Treatment plant and distribution system operators have perhaps the most direct influence on the safety of a community's drinking water supply. For this reason, it is very important for system owners to require that only system operators with the appropriate training be hired. The operators' level of competence also needs to be maintained through continuous education opportunities.

It is important for the level of training to be appropriate to the treatment and distribution system being managed. All operators require a basic understanding of water quality issues, especially those related to the microbiological quality of the water and the need for proper disinfection. It is important for those responsible to be given specific training on how to optimize, and react to changes associated with, the more complex treatment processes for any system that rely on these processes. Training should thoroughly explain monitoring processes and how to maintain documentation and keep records. Employees need to fully understand emergency response and reporting procedures. In addition, education on source water protection issues is important as waste streams from treatment systems can impact source water quality, especially for downstream water users.

Training can include formal training at post secondary institutions, water association training courses, in-house training and mentoring programs, on-the-job experience in consultation with other trained operators or government specialists, workshops, seminars, courses, and conferences. Operator certification ensures that operators are appropriately trained to the level required for the system they are responsible for. It is important that provincial and territories governments require mandatory certification, and that system owners commit to supporting such programs. Because training is an on-going process, employee training needs to be a continuous commitment.

Detailed information about operator training and certification, along with facility classification, is found in Section 8.6.

3.7 Research and Development

Growing demands on drinking water quality and quantity are creating an urgent need to link research from a wide range of sources in order to improve drinking water quality from source to tap. Existing uncertainties in the drinking water field can only be overcome by a greater scientific understanding of issues. This understanding is normally attained through research and development, which enhances our understanding of threats to water supplies. Technology development provides mechanisms to counter these threats. Research and development most often provide interpreted assessments that clarify both technical and operational issues. In addition, it is recognized that investment in prevention will always be far less costly than remediation of problems or dealing with situations of irreversible harm.

It is important for all stakeholders, including governments, to maintain awareness of the research and development occurring in the national and international scientific communities. Sharing information between jurisdictions allows each jurisdiction to determine applications to its local situation. Stakeholders need to commit to gathering data and maintaining databases on water quality parameters for which there are water quality guidelines, new and emerging substances of concern, and associated treatment technologies.

It is important for regulators, consultants, facility operators and other stakeholders to commit to continually bettering the information and knowledge-base on water treatment processes and hazards, new processes and emerging issues, improved analytical methodologies, the relationship between water quality and health outcomes, and local water quality and treatment data gathering. Government needs to actively participate with institutional and public sector researchers and monitor the results of research to ensure priorities are being met.

Provincial and territorial governments need to maintain their knowledge of the advances in disinfection and treatment process optimization within and outside of their jurisdictions. Sharing information allows each jurisdiction to determine applicability to its local situation. It is important for provincial and territorial governments to commit to gathering data and maintaining databases on the water quality parameters currently included in the guidelines, new and emerging substances of concern, the treatment technologies and limitation within their jurisdictions, and the efficiencies of the treatment provided.

Drinking water suppliers also need to commit to gathering data, optimizing their processes, and to cooperating with the provinces and territories in data collection to assess public exposure to various substances under consideration for guideline development or review. Since this information feeds into research processes, water suppliers and public health officials play an important role by collecting data about their water systems and the health of the community. They should be encouraged to cooperate and participate in research activities.

Regional health departments and the various partners involved with delivering health care also have a role to play by helping gather data on disease occurrence and prescription and non-prescription medications. This type of data helps identify whether the contaminants or pathogens in question are entering the system or are a concern in Canadian drinking water supplies. Comparing water quality data to local hospital admittance records, medical billing records, or sales of over-the-counter pharmaceuticals can sometimes indicate relationships between water quality and potential health effects. This data may form the basis of new or revised public health policies.

It is important to use scientific information as the basis for making decisions whenever possible. Drinking water managers are often forced by circumstances to make decisions based on incomplete knowledge. They compensate by filling information gaps with reasonable assumptions. Each such assumption carries the risk of unintended consequences. Use of scientific data in decision making has the advantage of controlling or measuring many of the important conditions that affect outcomes; critical assumptions are often carefully spelled out. When decisions are based on anecdotal experience, less may be known about conditions that affect outcomes, and key assumptions about these conditions may not be explicit. Decisions that draw on scientific information, therefore, reduce the risk of unexpected outcomes.

As noted, many stakeholders are involved directly and indirectly in water issues. The goals of stakeholders may differ and thus provide conflicting interpretations of priorities and responsibilities. For this reason, it is important for all levels of government and departments to work together in developing and implementing research and development activities.

Technology should not be developed in isolation. Decision-makers need to know how technology developed in academia, the private sector or through government research and development activities can be transferred for use in day-to-day operations. For example, the identification and control of threats posed by waterborne pathogens require effective pathogen detection and treatment techniques. Similarly, nutrient management plans and codes of practice need to be developed to reduce nutrient loading from specific sectors that have broad geographic coverage. Research on environmental indicators, technologies to recover and recycle nutrients, and management practices that minimize nutrient losses require greater attention.

4. The Risk Management Process

Risk management is a process that identifies all the existing and potential hazards in a drinking water system (from the watershed/aquifer and intake through the treatment and distribution chain to the consumer), assesses their potential impact on drinking water quality and public health, and then finds ways to either mitigate or eliminate those hazards. The goal of risk management is to protect public health consistently over the long-term.

Risk management

The systematic evaluation of the water supply system, the identification of hazards and hazardous events, the assessment of risks, and the development and implementation of preventive strategies to manage the risks.

Framework for management of drinking water quality: A preventive strategy from catchment to consumer

NHMRC/ARMCANZ
Co-ordinating group, Australia

The adoption of a risk-based approach, such as the multi-barrier approach, is essential to the effective management of drinking water systems. Hazard identification and risk assessment are valuable tools for understanding the vulnerability of a drinking water supply and for planning effective risk management strategies to ensure drinking water is kept clean, safe and reliable. In cases where risks cannot be quantified (*e.g.* when there are too many variables to isolate specific hazards or their potential impact), best management practices may be a useful tool for addressing risks.

4.1 Identifying Hazards

Hazards can be pre-existing in a drinking water supply, such as naturally-occurring minerals in a drinking water source that may need to be removed in order to protect public health over the short- or long-term. Hazards can also be potential, such as flooding or power system failures during a storm.

Hazard refers to a source of (potential) harm to the functioning of any aspect of the drinking water system or to human health. Hazards can be the result of natural and/or human (anthropogenic) activities.

Risk refers to the chance or possibility of a hazard causing this harm to the functioning of any aspect of the drinking water system or to human health.

In order to determine the inherent, existing and/or potential hazards within a specific drinking water system, owners and operators need to consult a number of sources of information. For instance, a detailed review of historical water quality data can assist in understanding source water characteristics and system performance both over time and following specific events (*e.g.* heavy rainfall). In addition to identifying hazards, this type of review can highlight those aspects of the drinking water system that require improvement.

When identifying hazards, all water quality data is considered including data from routine and investigative monitoring. Where possible, data is taken from source water monitoring, treatment plant and distribution system monitoring, and indicates the quality of finished water supplied to consumers. It is important for care to be taken to ensure the data is valid and not misleading, that proper sampling procedures have been used, and that consideration has been given to the location of the sampling sites and the season in which the samples have been taken.

It is important for all potential hazards and hazardous events to be considered and documented regardless of whether or not the system owner or operator has direct control over the hazard or its source. Potential source water hazards include point sources of pollution, such as human and industrial waste discharge, as well as diffuse sources such as those resulting from natural processes (*e.g.* decay of vegetation), agriculture, logging, mining and other land-use activities. Continuous, intermittent or seasonal pollution patterns should also be considered along with extreme and infrequent events such as droughts or floods. Potential operational hazards include lack of a cross control program, untrained operators, inadequate treatment, etc. Lack of historical data and/or source data may make the identification of some operational hazards more difficult.

4.2 Assessing Risks

Once potential hazards and their causes have been identified, the level of risk associated with each hazard and/or hazard scenario is estimated so priorities for risk management action can be established and documented. It is important to recognize that while countless contaminants can compromise drinking water quality, not every potential hazard will require the same degree of attention. The distinction between hazard and risk needs to be understood so attention and resources can be directed to actions based primarily on the level of risk associated with, rather than just the existence of, a hazard.

The level of risk for each hazard/scenario can be estimated by identifying the likelihood of occurrence. This likelihood of occurrence is then balanced against the severity of impact and the potential threat to public health posed by exposure to the hazard and the potential duration of this exposure. In some cases, such as exposure to some microbiological pathogens, the threat to public health will be acute even when the duration of exposure is fairly short. In other cases, such as exposure to some chemical contaminants, the hazard may only pose a threat to public health if people are exposed continuously over a period of years. Chemical contaminants, however, may also cause significant changes to the characteristics of the source water body and may necessitate changes in the water treatment process. Public perception of such contaminants and failure to adjust/change the water treatment process can lead to increased public health risks and a loss of consumer confidence. Consumers may seek other sources of drinking water that may not be free of pathogens.

Rarely will enough knowledge be available to complete a detailed quantitative risk assessment; in most cases it will be more appropriate to adopt qualitative or semi-quantitative approaches. Risk assessment approaches need to be transparent and fully understood by involved parties.

The predictive nature of hazard identification and risk management dictate that substantial uncertainty will always be associated with these activities. An appreciation of the uncertainties in our scientific tools is an important part of a precautionary approach to managing risks.

4.3 Managing Risks

Once hazards have been identified and their level of risk has been assessed, they are prioritized and then managed. The type of risk management strategy required depends entirely on the type of hazard requiring attention. For instance, in order to mitigate the risk associated with a potential power outage during a storm, a utility may simply need to arrange to have an alternative power supply on-site such as a back-up generator.

Other hazards may require much more extensive or complex risk management solutions. For instance, while diffuse sources of pollution arising from agricultural and other land use activities are more difficult to manage than point sources of pollution, their effect on public health can be minimized by adequate disinfection. The amount of microbiological contamination can be minimized through the use of best management practices such as fencing off streams, managing riparian zones and watering livestock off-stream. Co-operation with landowners and agricultural advisors in the development of joint land and water management strategies is important. The proper design and on-going maintenance of treatment plants and distribution systems is essential to protecting public health.

Weighing risks and benefits

The net change in risk produced by treatment processes such as disinfection and the addition of other essential chemicals is a trade off between decreasing infectious disease and increasing toxicological risk. Where appropriate information exists, a quantitative risk assessment approach should be used to evaluate the risks. Risk assessment results should be considered as tentative because they are far from being inclusive of the total microbial and toxicological risks. Furthermore, the assumptions that typically underlie risk assessment models used are difficult to verify experimentally.

Risk management tools and processes often involve costs that must be weighed against the real or potential benefits associated with implementing and maintaining them. Often the calculation of costs vs. benefits is complicated by stakeholders having differing views on the acceptability of various risks. Some people may feel that no risk to their health is acceptable, even if the scientific evidence is ambiguous or lacking and the cost of implementing a barrier to eliminate the risk is high. Others may feel more comfortable with some risk of health effects if they know these effects are minimal and would only affect a very small number of people over the long-term. People at risk such as the immune compromised would be advised and they could take preventive measures to protect their own health.

Prioritizing risks

Many jurisdictions in Canada are developing procedures for prioritizing risks to drinking water from source to tap. For more information on how this is being done in your jurisdiction, contact your provincial or territorial drinking water authority.

It is important to remember that while no approach will guarantee 100 per cent protection all of the time, effective risk management reduces the risk of illness from drinking water and increase the feasibility and effectiveness of remedial control or preventative options. As a safeguard, a key element of the multi-barrier approach is to ensure contingency plans are put in place to respond to incidents as they arise, and that redundancies are built into the system wherever feasible. These actions will mitigate repercussions when and if failures occur in the system and also help demonstrate that the system owner and/or operator has acted with due diligence.

4.4 Risk Communication

Risk communication is an equally important component of the risk management process and should not be overlooked. Risk communication refers to the exchange of information between interested parties about health or environmental risks, the significance of these risks and actions aimed at their management and control. It is an on-going process; risk communication should not only be used during a crisis or emergency.

> Risk communication is an integral part of the decision-making process, because risk management decisions must be acceptable to a broad range of interested and affected parties.

Effective risk communication ensures all participants adequately understand the risk management process and decisions made. It helps participants make informed decisions about the factors that can affect their health such as the quality of their drinking water. (Adapted from Health Canada 2000).

5. Drinking Water Hazards

This section discusses the most common hazards to the drinking water supply, from source to tap. The assessment and management of these hazards is discussed in Sections 6, 7 and 8.

The first step in implementing the multi-barrier approach is to understand the drinking water supply, including: the quantity and quality of the source water; the current and potential hazards that could impact that quantity and/or quality; the treatment processes in place and their limitations; and the condition of the distribution system.

Drinking water is either taken from surface waters such as lakes and rivers or groundwater sources such as aquifers. The types of hazards that need to be assessed and managed vary depending on the type of the source water, its geographical location, the local geology, and the activities that take place in or around the watershed/aquifer. For instance, human and animal populations can contribute microorganisms and nitrate loadings from wastes. Human development pressure from private sewage disposal systems (*e.g.* septic fields), landfills, and industry and agriculture can put source waters at risk of contamination. Industrial and construction operations can release large amounts of heavy metals. Farming operations can result in runoff containing fertilizers and pesticides.

In addition, the destruction of wetlands in many jurisdictions has threatened source water quality by removing the pre-existing capacity for source waters to be buffered from pollution sources. The absence of wetlands means pollutants that would otherwise be effectively filtered by natural biological and physical processes readily enter source waters. Currently, many federal and provincial programs are trying to reverse this trend and reclaim areas around source waters as wetlands.

An examination of existing land uses can, on a preliminary basis, identify the types of hazards that may exist in source waters. These assessments can guide regulators to focus their monitoring efforts on the likelihood of findings potential contaminants that may be present due to the land use activities.

Once source water has been collected at the intake for treatment and distribution as drinking water, microbial and chemical constituents can be introduced. Possible causes of contamination include improper sanitation practices of staff and visitors, improper construction of works, improper operation of treatment or distribution system components, misuse of treatment chemicals or additives, and process failures. It is important that the design and operation of waterworks systems follow good engineering practices. *These practices are discussed in more detail in Sections 7 and 8.*

Potential health impacts of microbial constituents are discussed below. The health effects of water treatment chemicals and/or additives are difficult to determine without knowing the precise concentrations of these substances at the consumer's tap. It is important to note that there are considerable benefits to using additives such as coagulants, flocculants and filtration compounds as they enable treatment plant operators to remove significant amounts of viruses and other microbes, particulates and other substances. Although extremely high levels of water treatment chemicals could cause adverse health effects, safe application rates of these substances are well established and published by organizations such as NSF International.

Scientific research has brought to light questions about the health effects of a number of microbiological pathogens and chemicals that may be present in water supplies. These substances include emerging pathogens, pharmaceuticals, and endocrine disruptors.

For more information on current research, see the Health Canada website at www.hc-sc.gc.ca/waterquality

For information on guidelines for pathogens and other substances found in drinking water supplies, see Section 3.4.

5.1 Microbiological concerns

Microbiological pathogens are considered the most significant threat to public health related to drinking water because the effects are acute; if ingested, pathogens can give people gastro-intestinal illness within a matter of hours or days. In some cases, consuming microbiological pathogens can result in permanent damage to internal organs or lead to chronic health problems. In the most severe cases, ingesting pathogens can be fatal.

For some **groundwater supplies**, the most significant sources of **microbiological contamination** are:

- Feedlots
- Land applications of biosolids or manure
- Irrigation with wastewater effluent
- Wastewater disposal fields
- Wastewater treatment facilities

Surface water is vulnerable to microbiological contamination from wildlife and a variety of human activities. Land use activities will affect to some degree the types of pathogens present. Pathogenic bacteria and protozoa will occur in watersheds containing livestock and wild animals and birds. Watersheds containing human populations will also contain pathogenic viruses. Concentrations of these pathogens at the treatment plant intake will depend upon factors such as human and/or animal population densities, source protection measures, pathogen persistence, dilution rates and proximity of the intake to the source of contamination.

Generally speaking, the microbiological quality of groundwater sources is better than that of surface waters because most microorganisms are removed as the water seeps through the soil. The soil acts as a natural filter. The longer it takes for water to reach the aquifer, the lower the probability of microbial contamination and the lower the risks to human health. The overlying soil and strata characteristics (topography, soil type, soil texture, soil permeability, soil saturation, and stratigraphy) determine the vulnerability of the aquifer to contamination. Understanding the physical characteristics of a groundwater recharge area is necessary to assess the vulnerability of the aquifer to contamination. The location of well heads and improper maintenance could increase the vulnerability of aquifers to contamination.

For **surface waters**, sources of **microbiological contamination** are:

- Grazing animals and feedlots
- Sewage discharges
- Wildlife populations
- Recreational activities
- Unrestricted human access
- Biosolids/manure

Traditionally, micro-organisms have been monitored in source water and finished drinking water as an indicator of the presence of pathogens (e.g. total coliforms). There are benefits and drawbacks of this methodology. *A detailed discussion of indicators of microbial water quality can be found in "Water Quality: Guidelines, Standards and Health" published by the World Health Organization.*

Regardless of the source of drinking water land use activities not only need to be managed to minimize the contamination of the source and but also recognized so that appropriate treatment can be provided.

MICROBIOLOGICAL PATHOGENS IN DRINKING WATER SOURCES

Microbiological pathogens are microscopic organisms such as viruses, bacteria, and protozoa. Their presence in source waters, even in small numbers, can cause disease or death in humans and animals if ingested water is not properly treated.

The kinds of microorganisms typically identified as potential threats to Canadian drinking water supplies include the bacterium *Escherichia coli* O157:H7, and the protozoa *Cryptosporidium* and *Giardia*. Less is known about the potential threat of water-based viruses.

For more information, check out the supporting documentation to the *Guidelines for Canadian Drinking Water Quality* or Health Canada's fact sheet series, *It's Your Health,* at www.hc-sc.gc.ca/waterquality

Escherichia coli O157:H7
E. coli is a coliform bacterium that exists exclusively in the intestines of humans and warm-blooded animals. As such, it is an ideal indicator of fecal contamination, and the possible presence of intestinal pathogens. More than 50 different strains of *E. coli* exist, and most are harmless (BCPHO 2001). However, some strains such as *E. coli* O157:H7 can cause severe illness in humans. Illness can result in bloody diarrhea, and in some cases kidney failure and potential death from hemolytic uremic syndrome (BCPHO 2001). Sources of *E. coli* contamination are animal wastes and waste water discharges which can be readily carried into ground- and/or surface waters during heavy precipitation.

Protozoa
Parasitic protozoa that have been found in Canadian drinking water supplies include *Cryptosporidium*, *Giardia lamblia*, and *Toxoplasma gondii*. *Cryptosporidium parbum* causes an illness known as cryptosporidiosis, while the *Giardia* parasite can cause giardiasis (also called 'beaver fever'). Both cryptosporidiosis and giardiasis are gastrointestinal illnesses. *Toxoplasma gondii* causes a flu-like

illness known as toxoplasmosis which can cause permanent damage to the fetus. The main sources of these parasites in drinking water are animal and human feces. Cattle feces are the main source of *Cryptosporidium*, while beaver, human, dog and other animal feces are the main source of *Giardia*. *Toxoplasma* mainly comes from the feces of domestic and wild cats. Like fecal bacteria, these parasites can be easily transported to source waters through runoff and percolation into groundwater. Agricultural, urban, and wildlife habitat land uses are potential sources of these parasites to source waters. Source water contamination by *Cryptosporidium* and *Giardia* is a great concern because these protozoa are more resistant to disinfection than bacterial pathogens.

Viral Agents
Viruses are extremely small microbes (<0.3 microns) that pose a risk to human health in untreated drinking water sources. They are hardier and persist longer in water supplies than bacteria (BCPHO 2001). Viral agents in source waters could include hepatitis A and E, rotaviruses (which cause diarrhea in infants and immune-compromised adults), and the Norwalk-like viruses (which infect healthy adults and children and may cause such symptoms as diarrhea, nausea, vomiting, malaise, fever for up to 48 hours) (BCPHO 2001).

5.2 Chemical and radiological contaminants

Health effects from chemical and radiological contaminants in drinking water tend to be chronic, appearing only after people are exposed to high levels of the substance consistently over a period of years. Generally speaking, only a small percentage of the population would see any effects. Health effects vary depending on the specific contaminant.

Chemicals and radiological compounds can threaten the quality of groundwater supplies. Groundwater normally contains higher amounts of dissolved minerals than surface water because it percolates slowly through the soil, gathering minerals as it travels. Many groundwater sources require treatment for aesthetic or operational reasons, such as to reduce hardness or concentrations of naturally-occurring iron or manganese. Groundwater sources may also have naturally elevated levels of elements such as fluoride, arsenic, or uranium that can pose a chronic health risk. Treatment is the only means to control their concentration to acceptable levels.

Significant sources of **chemical contamination** from human activities are:

- Industrial operations
- Mining
- Spills and releases
- Hazardous waste facilities
- Petroleum products storage facilities
- Agriculture
- Domestic use of chemicals and personal care products
- Waste water discharges

The land use within the watershed/aquifer can also affect the chemical quality of groundwater sources. For instance, if an industrial operation is located within the watershed/aquifer, the groundwater might contain industrial chemicals or heavy metals. Agricultural practices could result in elevated levels of nitrate-nitrite, nitrogen or pesticides.

Surface water is also vulnerable to chemical contamination from natural sources and human activities (anthropogenic sources). The types of chemicals present are site-specific and depend on the activities that take place within a given watershed/aquifer. For instance, mining activities can cause elevated heavy metal concentrations and depressed pH; livestock or wastewater discharges can cause elevated nitrate-nitrite levels, and industrial operations can be a source of synthetic organic compounds.

CHEMICAL CONTAMINANTS IN DRINKING WATER SOURCES

General categories of chemical contaminants include organic chemicals (such as most pesticides) and inorganic chemicals (such as metals, total dissolved solids, and nutrients). Historical uses of chemicals that are now banned from production still pose a risk to source water quality.

Organic Chemicals
Organic chemicals contain carbon molecules in their structure. Many organic chemicals have a harmful effect on human health and can pose a direct threat to a source water supply. Organic chemicals are found in point- and non-point source releases from a wide variety of users, including industrial, agricultural, municipal and residential sectors. Larger point-source releases may occur from industrial effluent discharges and/or accidental industrial releases.

Pesticides
Pesticides are primarily organic chemicals used to control pest organisms such as unwanted plants and insects. Pesticides are readily used in urban, agricultural, aquacultural, and silvicultural applications, where they can reach source waters through direct application, surface runoff, and/or groundwater percolation. Pesticides used for herbicidal and insecticidal purposes in urban and agricultural regions have been detected in surface and groundwaters, demonstrating the need for diligent monitoring of drinking water sources for regionally important pesticide products.

Total Organic Carbon
Total organic carbon (TOC) is a measure of the amount of organic material suspended in the water. TOC is not a direct threat to water quality but rather an indirect threat. When organic carbon combines with chlorine used in the disinfection of treated drinking water, disinfection by-products (DBPs) such as

trihalomethanes (THMs) are produced.

Emerging Issues
Scientists are now beginning to look at more closely at pharmaceuticals and personal care products (PPCPs), some of which may also be endocrine disruptors.

The NWRI has focused research on endocrine disruptors and PPCPs. Although there is currently little research linking human health effects directly to these substances, there is preliminary evidence of ecosystemic effects from endocrine disruptors. This underlines the need for further research into their potential human health effects as both have been detected in water at extremely low concentrations. The capacity of conventional drinking water treatment to remove these contaminants is limited and dependent on their characteristics (e.g. stability, etc.).

Risks to human health posed by these contaminants in drinking water are expected to be low but need to be studied further. In comparison, the human health risks of other contaminants such as pathogenic microorganisms and arsenic are well characterized and are currently considered to be a priority.

Inorganic Chemicals
Inorganic chemicals include metallic and non-metallic chemicals that can be dissolved in a water source. Inorganic chemicals range from those that have moderate, or no negative impacts on human health (*i.e.*, fluoride, chloride), to those that are highly toxic to humans (*i.e.*, cyanide). Potential sources include both natural processes (*i.e.*, weathering and dissolution of salts) and discharges from human activities such as effluent releases and runoff associated with industrial operations.

Metals
The presence of dissolved metals in water supplies can have a negative impact on human health through direct toxicity or by compromising the aesthetic value of source waters. Metals can enter source waters from natural weathering processes and through sources such as industrial and municipal effluents, mining, leachate from waste disposal grounds and pesticide use. Metals of concern in Canadian drinking water supplies can include (but are not limited to) aluminum, arsenic, chromium, copper, iron and lead (CCME 1999a).

Water quality characteristics such as pH and the presence of humic materials can greatly influence the availability of metals to humans and biota, and it is therefore necessary to monitor such site-specific factors when high metal contents are found in drinking water sources. Guidance on the effects of modifying factors to metal bioavailability can be found for individual parameters in the Canadian Environmental Quality Guidelines (CCME 1999a), and in the supporting documentation of the Canadian Drinking Water Guidelines from Health Canada (2001).

Total Dissolved Solids
Total dissolved solids (TDS) are inorganic particles and small amounts of organic matter that are dissolved in water. The principal constituents are usually calcium, magnesium, sodium, and potassium cations and carbonate, hydrogen carbonate, chloride, sulphate, and nitrate anions.

TDS in water supplies originate from natural sources, sewage, urban and agricultural runoff, and industrial wastewater. Concentrations of TDS from natural sources vary greatly depending on the solubilities of minerals in different geological regions.

Water supplies, high in TDS, are not considered a direct public health threat, other than aesthetic effect. Its presence does, however, mitigate the effects of other chemical threats such as metals (toxicity of some metals is dependent on TDS in freshwater) or accentuate the threat of pathogens in water supplies (pathogens adhere to TDS particles, which hinders their disinfection thus requiring a higher level of treatment). Therefore, TDS can be an indirect measure of the presence of other contaminants.

Nutrients

Nitrogen and phosphorus are two key nutrients, which contribute to the growth of algae and plants in aquatic ecosystems. Nitrogen in its inorganic form can present both a direct and indirect threat to a water supply. Consumption of drinking water high in nitrate ions (the most commonly found soluble form of nitrogen) can cause methaemoglobinemia in infants, a condition also known as "blue-baby syndrome." This condition impairs the ability of the blood to carry oxygen and can be fatal to infants younger than six months old.

Because nitrogen is also an essential plant nutrient, excessive amounts can promote the growth of algae in water. The principle natural sources of nitrogen to the aquatic environment come from the breakdown and recycling of organic matter and the deposition of nitrogen compounds from the atmosphere. Agricultural and industrial processes can greatly increase the amount of nitrogen reaching source waters.

In contrast to nitrogen, phosphorous has no direct impact on human health. However, excessive loading in water can lead to indirect deterioration of water quality by promoting algae growth. Algae can cause nuisance problems in the water supply by contributing to taste and odour. Very high levels can raise turbidity, leading to interference with water treatment processes.

The death of algal blooms contributes to oxygen depletion in water bodies, which can have severe ecological effects and can also alter chemical redox processes. These, in turn, can influence chemical speciation.

The influx of phosphorous supports the growth of most species of cyanobacteria (blue-green algae) which can contain toxins that are released into the water when the organism dies. These toxins could result in a direct threat to human and animal life. For most cyanobacterial species, the potential for growth is increased when phosphorus levels are increased without a corresponding increase in nitrogen (*i.e.* a low Nitrogen to Phosphorous ratio favors the development of cyanobacteria blooms).

Phosphorous is naturally released from the dissolution of phosphorous rich rocks and minerals. Potential sources from human-based activities include run-off and leachate from agricultural and lawn fertilizers, sewage (including waste effluent and septic disposal), manure from livestock, and industrial effluents.

5.3 Physical water quality parameters

In addition to threats from chemicals and microbiological pathogens, the quality of source waters can be impacted by a number of physical characteristics. These site-specific characteristics can result from the amount of organic matter suspended in the water or its mineral content. Other physical characteristics include odour, temperature and pH.

Physical characteristics do not normally present a direct threat to human health. However, they can indicate the presence of other chemical or biological concerns. Particulate matter, which leads to turbidity, can also interfere with drinking water treatment processes, thereby increasing the risk of microbiological threats. More information on the physical characteristics of water is given in the box below.

PHYSICAL WATER QUALITY PARAMETERS

Turbidity
Turbidity refers to the suspension of small particles of sediment and organic matter within the water source that causes an overall cloudy appearance. Unstable soil conditions in the riparian zones of watersheds can contribute to turbid conditions in source waters. Turbidity generally increases as water velocity increases within the stream or river, as deposited material can become resuspended in the water column. Organic and inorganic particulates have no notable health effects, however they can often harbour micro-organisms. In many cases, elevated turbidity levels protect micro-organisms from disinfection processes. Turbidity is an important water parameter to monitor as elevated levels can impair several uses of a water source, including drinking water, industrial and recreational uses, and environmental health.

Colour
Colour is derived from the backscatter of light passing through the water, and is influenced by the dissolved or suspended constituents in the water. Colour can be the result of natural factors (*e.g.*, dissolution of iron from iron-rich minerals, and dissolved humic materials) or factors that result from human-based activities such as effluent discharge from industrial activities.

The source of the colour may influence the toxic effects of other contaminants. For example, highly tea-coloured water resulting from the presence of humic acids has been shown to reduce the bioavailability (and therefore toxicity) of metals such as aluminum, zinc and copper, while increasing the bioavailability of mercury (CCME 1999a).

Elevated humic levels in highly coloured waters may also interfere with water treatment processes, and result in the production of potentially carcinogenic by-products like THMs.

Taste and Odour
Taste and odour problems in source waters are primarily an aesthetic concern, however, they can undermine consumer confidence in water supplies, and result in millions of dollars annually in treatment costs to the water industry (Watson et al. 2002).

Taste and odour problems in the Great Lakes region and in Western Canada have been attributed to the presence of the biological metabolites geosmin and 2-methylisoborneol (MIB) from certain species of cyanobacteria and/or actinomycetes. Production of these compounds may be promoted by local point-source urban run-off.

pH
pH is a measure of the hydrogen ion concentration in water (or other solution). Waters with a pH of 7.0 are neutral, while levels < 7.0 are acidic and > 7.0 (up to a maximum of 14) are alkaline (or basic). A one-unit change in pH represents a ten-fold change in hydrogen ion concentration; therefore, even small changes in pH can significantly alter the chemistry of source waters. The pH of aquatic environments can be depressed by the release of spring snowmelt containing atmospherically deposited SO2 and NOx, or by the direct release of acid mine drainage and some types of industrial waste leachates (CCME 1999b).

Changes in pH levels can alter the chemical form of some contaminants. For example, a reduction in pH may mobilize some heavy metals into solution.

Temperature
Temperature affects both biological and chemical functions. Chemical equilibrium constants, solubilities, and the rates of chemical reactions are all temperature-dependent (CCME 1999c).

For more information on how physical characteristics of water affect drinking water treatment, see Section 7

5.4 Interactions between contaminant categories

Although the hazards discussed are present in separate categories, it is important to note that the different types of hazards could interact with one another. This interaction may result in synergistic (*i.e.* the toxicity of one hazard is increased in the presence of another) or antagonistic (*i.e.* the toxicity of one hazard is reduced in the presence of another) effects. For example, the presence of increased turbidity can lead to micro-organisms in a water supply. Therefore, the potential interactions between contaminant sources should be considered when identifying potential hazards. Current drinking water standards do not consider the effects of exposure to multiple hazards due to the variability and complexity of these effects. Continued research is needed on the potential impacts of multiple hazard exposure.

5.5 Unexpected Events

Unexpected events (either natural, or as a result of human error or accident) have the potential to impact water quality and therefore need to be considered in the watershed/aquifer characterization.

The potential for impact from unusual natural events will likely be identified during the assessment of other watershed/aquifer characteristics, such as topography and vegetative cover. Such events could include rainstorms, blizzards, landslides, mudslides, floods, etc.

Unusual events caused by human activities would likely be related to unplanned chemical releases into a watershed/aquifer. Unplanned releases can occur as a result of operational failure at an industrial facility, treatment plant error, or transportation accident.

> Statistical summaries of extreme weather events from regional weather offices would indicate the probability of adverse events occurring which may influence ground- and surface source waters, particularly heavy rains and flooding.
>
> The type and probability of unexpected events occurring within a watershed, and their potential effect on source waters, should be assessed from historical spill records which may be available from the provincial/territorial ministries of environment and/or transportation.

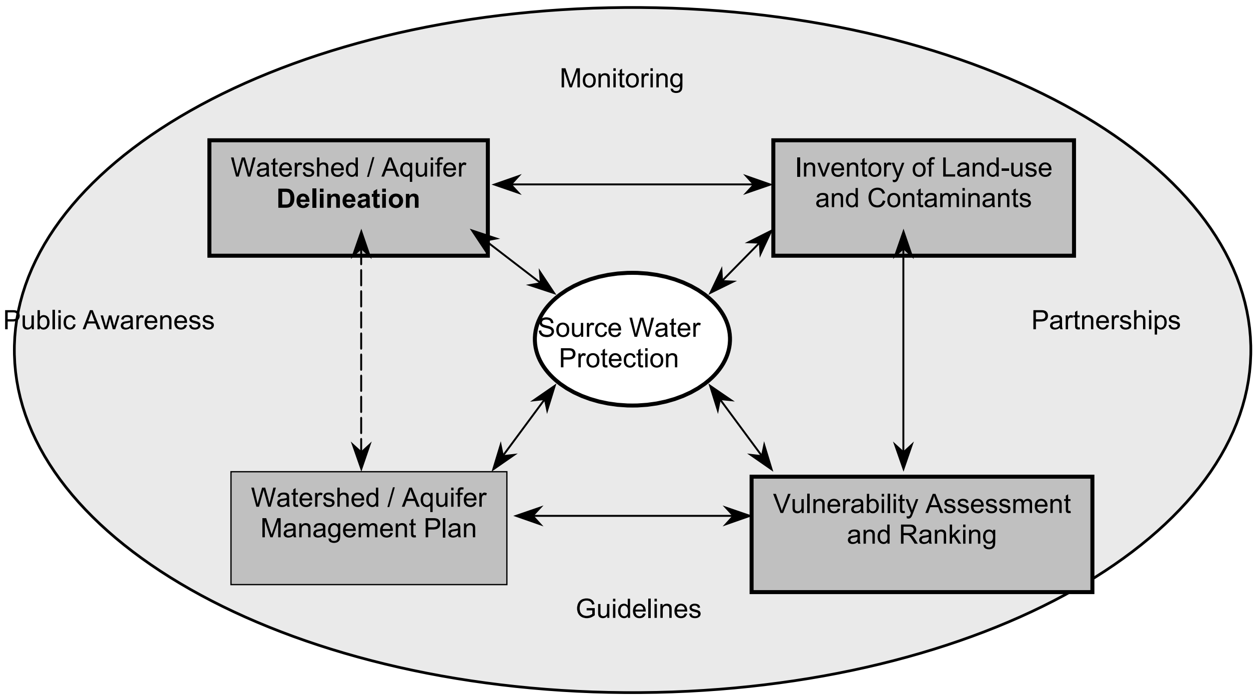
For more information on incidents and emergencies, including vandalism, see Section 8.8

6. Source Water Protection

In any drinking water system, protecting source water is a critical step towards avoiding drinking water contamination. It is also key to maintaining the quality of a drinking water source over time. Protected watersheds will improve the quality of the source water and impact the type of treatment technology needed to ensure safe drinking water. Regardless of the source water quality, however, all surface waters should, at a minimum, be disinfected to inactivate pathogens as these may be present in the most pristine water supplies.

Source water protection (see Figure 6.1) based on watershed/aquifer management involves a coordinated approach among stakeholders to develop short- and long-term plans to prevent, minimize, or control potential sources of pollution or enhance water quality where necessary. Source water protection planning is an evolving process; management plans should be reviewed periodically to ensure that the most effective solutions are being applied and that the experiences of other groups working towards similar goals are acknowledged and incorporated where appropriate. It is important to note that because watershed/aquifer management is an on-going, long-term commitment, not all elements need to be in place prior to a source being treated and used for drinking water.

Figure 6.1 Components of Source Water Protection



The components of a source water protection strategy can be divided into a source water assessment and an implementation plan to deal with the results of the assessment, achieved through a Watershed/Aquifer Management Plan. A source water assessment is comprised of:

- Delineating source water protection areas
- Identifying contaminants of concern through various inventories (such as contaminant or land use inventories)
- Assessing the risk vulnerability and rank

Once the assessment has been completed, a Watershed/Aquifer Management Plan can be developed. This plan introduces measures to reduce the risks identified in the assessment. The initial assessment also guides the selection and design of appropriate treatment and distribution systems to ensure the water reaching consumers is safe to drink.

For a summary of source water protection measures taken in Canada, see Appendix B.

For more information on selecting and designing appropriate treatment and distribution systems, see Section 7.

6.1 Source Water Assessment

The assessment of the drinking water supply forms the basis of all activities related to providing safe, aesthetically pleasing, and reliable drinking water to the public. Assessments identify the characteristics of the water source, identify potential health hazards, how these hazards create health risks to the population consuming the water, and how these health issues can best be managed. As such, a source water assessment serves three critical purposes:

1) To identify whether a body of water is a suitable source for drinking water
2) To identify the level of treatment required in order to make the water safe to drink
3) To target the activities of the Watershed/Aquifer Management plan

It is very important for all water supply assessments to be made against the appropriate provincial or territorial treatment plant performance criteria and compliance monitoring requirements (see Sections 7 and 8). In addition, the potential source water needs to be assessed to determine whether it qualifies as a possible source of drinking water by looking at the potential hazards discussed in Section 5 and the treatment and/or other barriers that would be required to minimize the health risks posed by these hazards.

The potential source water should be assessed to determine its quantity, reliability, vulnerability, quality, and potential for future degradation. If the water source is insufficient or unreliable, and water balancing or conservation are not practical, alternative sources need to be considered. The quality of the source water influences the nature of the treatment processes required to reduce the potential health risks and produce safe and aesthetically pleasing water to consumers (see Section 7). Table 6.1 shows the factors that may affect source water quality.

Table 6.1 Factors Affecting Source Water Quality

Natural Factors	*Human Factors*	
	Non-Point Sources	**Point Sources**
Climate	Agricultural cropland runoff	Industrial discharges
Topography	Livestock/grazing	Wastewater discharges
Geology	Dairies and feedlots	Hazardous waste facilities
Soil cover	Urban development runoff	Mine drainage
Vegetation	Septic tanks	Spills and releases
Fire	Erosion	Urban runoff
Wildlife	Forest management	Combined sewer overflows
Saltwater Intrusion	Mining	Aquaculture
Density/thermal stratification	Recreational activities	
Erosion	Atmospheric deposition	

For more information on source water quality monitoring, see Section 8.1.1.

When selecting a water source, the requirements of other administrative authorities with respect to water rights, ground water exploration, environmental impacts, planning, and intake siting, etc., should be reviewed and applicable consultation should be undertaken. As well, it is important to consider and resolve effects from or on other owners. It is important to obtain required approvals from other authorities as soon as possible.

All source water assessments should proceed in stages, with each successive stage providing more layers of detail, until an adequate amount of watershed/aquifer data is collected to decide how best to minimize risks to their source waters. The initial step in assessing source water quality is to take stock of both the quantity and quality of water sources used as a supply of drinking water, followed by an assessment of who is using those waters, and for what purposes.

6.1.1 Delineating the Watershed/Aquifer Area

As mentioned in Section 5, there are two main sources of water supplies: surface water from lakes and rivers and groundwater sources that supply wells. Although viewed as separate, they are interconnected since they are both part of the earth's water cycle (hydrologic cycle), and can exert their influence on one another. For this reason, each water source should be developed and managed with careful attention to the hydrologic and ecologic systems of which the particular source is a part. Surface and groundwater sources should be managed conjunctively.

The quality of source waters used for drinking water is directly dependent on the quality of waters supplied by the watersheds/aquifers (*e.g.,* surface runoff, upstream surface water flow and ground water recharge). Delineation of a watershed/aquifer involves identifying the surface and subsurface areas of land that water passes through to reach a drinking water intake point. This allows water managers to define potential sources of contamination to their water supply, and because water travel times can be estimated to intake areas, provides them with an adequate lead time to intervene if a contamination event occurs.

The watershed/aquifer consists of all land and water areas drained by a watercourse and its tributaries. Sub-watersheds are areas drained by an individual tributary to the main watercourse (Watershed Planning Implementation Project Management Committee 1997). The processes for defining the physical boundaries for a watershed/aquifer relies on establishing the drainage patterns for the major regional watercourse(s) based on the topographic relief of the area.

Identifying watersheds/aquifers that feed drinking water sources, and providing a brief description of their current source status, allows water resource managers to rank the importance of watersheds/aquifers or sub-watersheds in supplying source waters to a particular town or municipality.

Surface Waters

Rivers, lakes and reservoirs act as the principle intake points for the drinking water resources of many communities. Rivers act as the major conduits for water movement within the watershed. Adequate protection of water sources to rivers (*e.g.* streams, overland runoff, or subsurface groundwater flow) is critical to ensuring high quality source water for drinking water.

Surface Water Uses

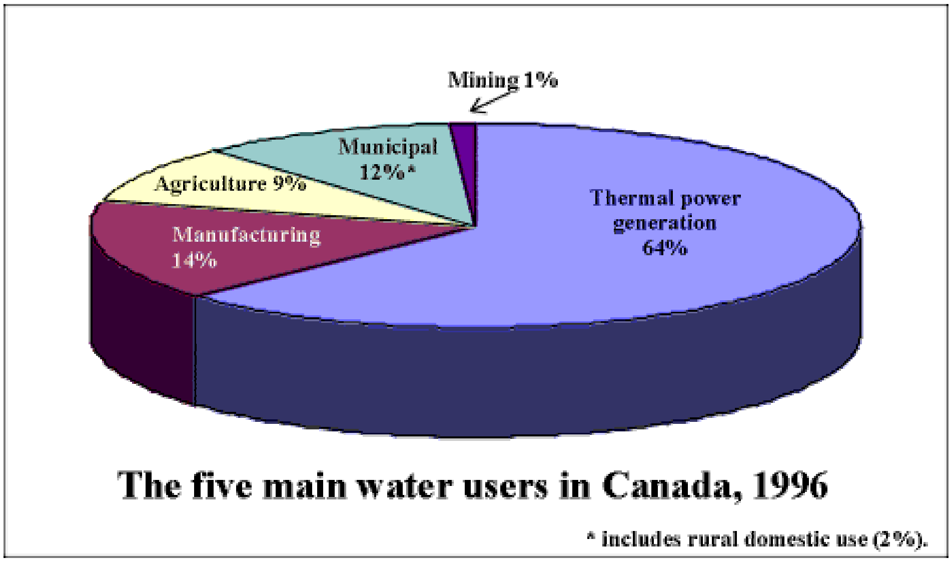
There are many beneficial uses of surface water that provide tangible values, and create economic opportunities within a watershed (see Figure 6.2).

- Drinking and domestic uses
- Recreational
- Aquatic and terrestrial wildlife
- Agricultural and industrial

Lakes and their man-made counterparts, raw water reservoirs, play a vital role as massive storage tanks and regulators of water flow. Historical geological lake formation processes contribute significantly to the present physical, chemical and biological interactions within a lake system (Wetzel 2001), and can therefore provide valuable information to lake managers in assessing current and future water quality trends. Both lakes and raw water reservoirs may be susceptible to direct discharges, pollutant loadings from overland runoff, atmospheric deposition, and nutrient and bacterial loadings from wildlife and human communities. In lakes, hydrology, lake stratification, internal cycling and productivity can also affect water quality (CTIC 2002).

Figure 6.2 Five main water users in Canada (1996)

This pie chart shows that the five main water users in Canada in 1996 were thermal power generation (64 percent), manufacturing (14 percent), municipal (12 percent), agriculture (9 percent), and mining (1 percent). The municipal figure (12 percent) includes 2 percent rural domestic use.
http://www.ec.gc.ca/water/en/manage/effic/e_how.htm



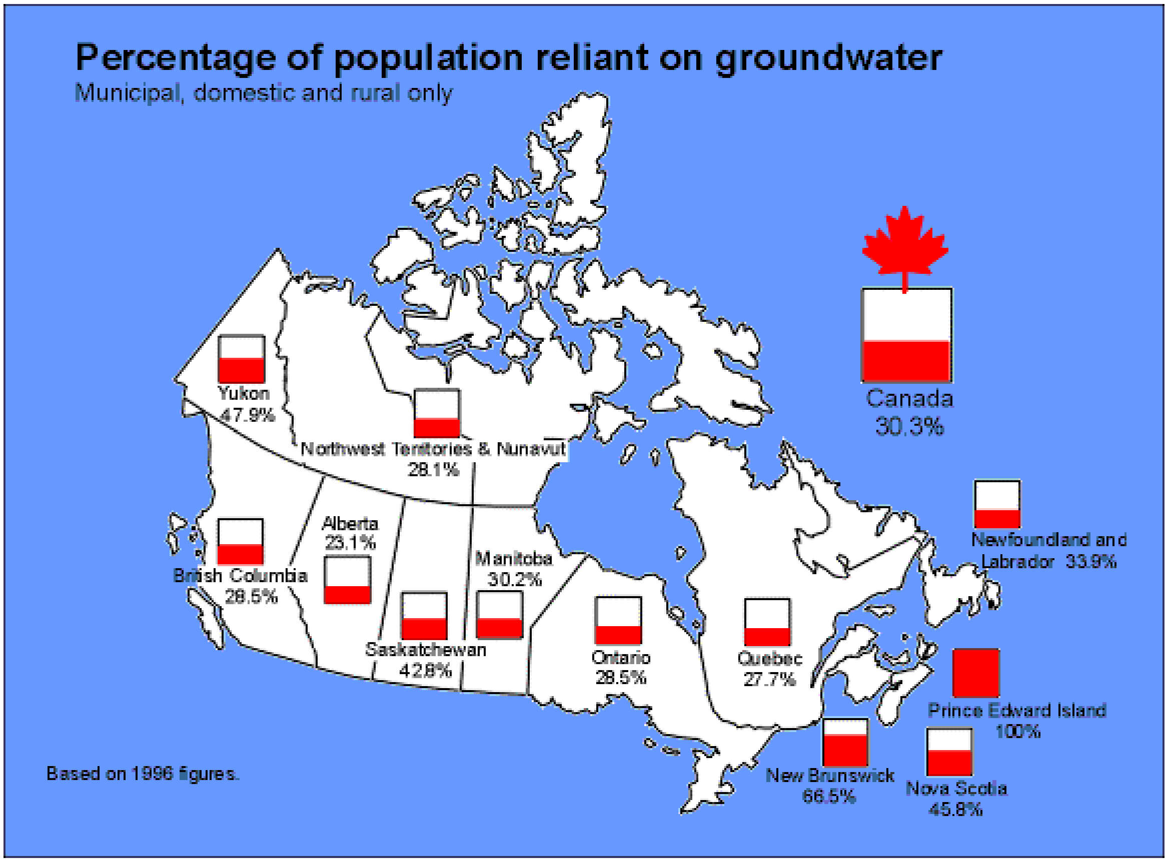
Groundwater

More than 7.9 million Canadians (or, about 26% of the population) rely on groundwater sources for their domestic drinking water. Two-thirds of all users are from rural areas, and the remaining one-third are primarily located in smaller municipalities where groundwater provides the principle water supply source.

Groundwater is accessed through wells dug or drilled into aquifers. Aquifers are geologic formations, or groups of formations that contain sufficient saturated permeable material to yield significant quantities of water to springs and wells. Groundwater generally moves quite slowly, particularly under non-pumping conditions, with velocities ranging from several feet per day to several feet per year depending on the nature of the aquifer. For this reason, groundwater can take much longer than surface water to recover from contamination. Gravity and pressure differences are important factors in groundwater movement. Topography or slope of the land surface can often be used as an indicator of flow direction and to a certain degree gradient of the water table. Because groundwater is hidden from plain view beneath the surface, contamination of groundwater sources can also be concealed. Extra vigilance is required to prevent breaches in water quality (Environment Canada

2002a). Figure 6.3 shows the percentage of the Canadian population that relies on groundwater.

Figure 6.3 Percentage of Canadian Population Reliant on Groundwater



The illustration shows the percentage of the population reliant on groundwater for municipal, domestic, and rural use only. Based on 1996 figures.

- Canada: 30.3 percent
- Alberta: 23.1 percent
- British Columbia: 28.5 percent
- Manitoba: 30.2 percent
- New Brunswick: 66.5 percent
- Newfoundland and Labrador: 33.9 percent
- Northwest Territories and Nunavut: 28.1 percent
- Nova Scotia: 45.8 percent
- Ontario: 28.5 percent
- Prince Edward Island: 100 percent
- Quebec: 27.7 percent
- Saskatchewan: 42.8 percent
- Yukon: 47.9 percent

Sources:
Statistics Canada, Environment Accounts and Statistics Division, special compilation using data from Environment Canada, Municipal Water Use Database.
Statistics Canada, 1996, *Quarterly Estimates of the Population of Canada, the Provinces and the Territories*, 11-3, Catalogue no. 91-001, Ottawa.

Surface Water under the Influence of Groundwater

Unconfined aquifers interact closely with streams and lakes. In situations where groundwater supplies surface waters, the aquifer feeds the stream or lake by discharging to the surface water. Streams can gain water from groundwater through the stream bed when the elevation of the water table adjacent to the stream bed is greater than the water level in the stream. If drinking water is taken from a surface water source, it is crucial to also assess the nearby-unconfined aquifer near the surface water body.

Groundwater under the Influence of Surface Water

Groundwater Under the Direct Influence of surface water (GWUDI) refers to groundwater with incomplete or undependable subsurface filtration of surface water and infiltrating precipitation. Inadequate filtration can result in risks to human health if drinking water is consumed without appropriate treatment.

When a well near a stream or surface water body begins to pump, the well initially obtains its supply of water from aquifer storage. The resulting decline of groundwater levels around the well creates gradients that capture some of the ambient groundwater flow that would have discharged as base flow to the stream. Eventually the well may draw upon the stream and induce flow out of the stream into the aquifer. The sum of these two effects causes stream-flow depletion. (Sophocleous et al., 1995)

The determination of whether a groundwater source is under the direct influence of surface water should be based on site-specific measurements of water quality and/or documentation of well construction characteristics and geology with field evaluation. For each groundwater source, direct influence should be determined in order to make an accurate assessment of a system's vulnerability.

For information on how to determine whether a groundwater source is under the influence of surface water, see "Investigation of Criteria for GWUDI Determination" (2001) AWWARF Report No ISBN 1-58321-116-0

For some examples of how Canadian jurisdictions determine GWUDI, see:

- *Nova Scotia's "Protocol for Determining Groundwater Under the Direct Influence of Surface Water" (December 2002) http://www.gov.ns.ca/enla/water/pdf/munguidp.pdf*
- *Ontario's "A Kit for Regulated Non-Municipal Drinking-Water System Owners (Drinking Water Systems Regulation O. Reg. 170/03)" (July 2003) Ontario Ministry of the Environment ISBN 0-7794-4899-5*

Inventorying Drinking Water Intake Points

All current and historical drinking water intake sites should be inventoried, and geo-referenced (*e.g.*, GPS) to determine the protection areas around these intake sites. Improperly maintained or managed intake sites could pose a contamination threat to current water supplies if improperly managed. Information on the number of active intake points for drinking water supplies and their locations can be determined by obtaining records of drinking water intake licenses from cities and/or municipalities. Permits for well drilling are issued through some provincial ministries. Data for private and municipal groundwater wells within a given watershed/aquifer can also be obtained from this source, though some jurisdictions may not collect data about the presence or location of private wells.

Delineating and Mapping Protection Areas for Surface Waters

Defining the zone of contribution to a drinking water intake point allows water managers to establish protection areas for those source waters. The box below outlines the three methods the US Environmental Protection Agency uses for delineating surface waters that contribute water to drinking water intake sites: topographic boundary delineation, streamflow time of travel (TOT), and setbacks/buffer zones (US EPA 1997b).

METHODS FOR DELINEATING SURFACE WATERS

Topographic Boundaries

Topographic maps are used for establishing watershed/aquifer boundaries by following the perimeter of high contour lines which indicate the direction of overland water flow within a geographical region. In the event that provincial Departments of the Environment or regional

Conservation Authorities do not already possess topographic maps delineating watershed/aquifer boundaries, topographic maps are produced by Natural Resources Canada (www.nrcan.gc.ca) at the 1:250 000 and 1:50 000 scales. Maps are also available from provincial governments.

The source water supply area for a watershed/aquifer is defined by the topographic boundary of the area within the watershed/aquifer that contributes surface water flow to a given drinking water intake site. This area can be easily delineated on a topographic map by drawing a line connecting the highest points within the overall watershed/aquifer that are uphill of that particular drinking water intake source, from which overland flow drains towards the intake.

Streamflow Time of Travel (TOT)
The TOT method is based on the amount of time it takes for a contaminant travelling at the same velocity as a stream to reach the water intake point. This method does not define a protection zone per se, rather it is intended to directly protect water quality at the site of drinking water intake by providing an early warning system for contaminants deposited in upstream waters. The TOT between a drinking water intake point and a monitoring site will vary depending on stream volume, and empirical hydrogeological flow models can be used to estimate travel times and contaminant concentrations at an intake site. Surface water travel times are on the order of hours within a regional watershed/aquifer. This would allow managers sufficient time to take appropriate measures to avoid the intake of contaminated waters. Note that this will not afford any ecological protection for sensitive species.

Setback/Buffer Zones
Setbacks and buffer zones around surface waters supplying source waters are used as a means of reducing impacts from runoff to drinking water sources by filtering overland flow, and encouraging ground water filtration. Buffer zones can take several forms, depending on the type of source water protection required. For example, sedimentation and contaminant transport to surface waters are often mitigated by riparian vegetation strips along streams or rivers, or constructed wetlands, while grasslands in agricultural areas reduce inorganic contaminants in groundwater supplies (Lowrance et al. 2002). These zones provide more time for natural remediation processes for contaminants in the overland flow, and can provide valuable wildlife habitat. The width of these buffer strips will depend on factors such as topography of the land, land uses, size of the stream, political and legal feasibility of designating the zones, and land ownership rights. The vegetative composition of the buffer zones will influence the amount of contaminant intervention occurring, with for example, grass buffers being less effective at nutrient removal than forested zones (Lowrance et al. 2002). The recommended typical riparian buffer width is in the range of 15 to 60 m (50 to 200 ft), depending on the degree of impact from land-based activities (US EPA 1997c; Lowrance 2002).

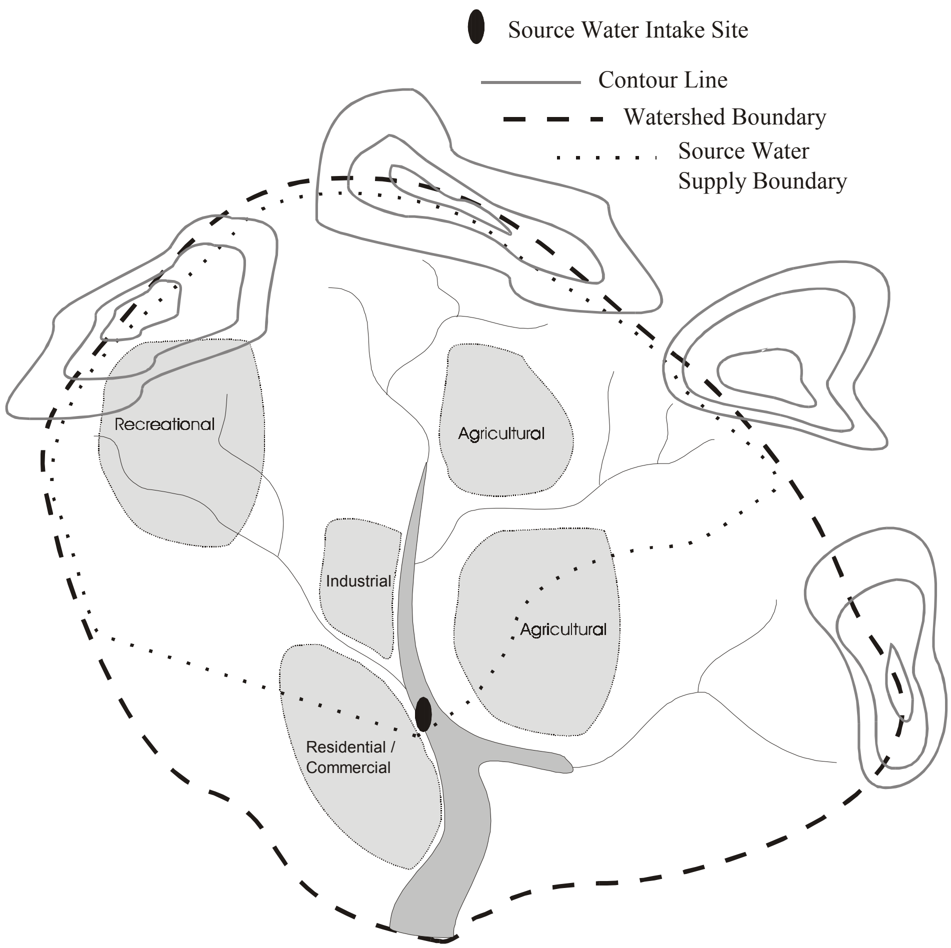
Delineating and Mapping Protection Areas for Groundwater

Although it is useful and generally recommended to also delineate the watershed/aquifer boundaries in which the source aquifer is located, watershed and aquifer boundaries are seldom coincident. Large aquifers can transcend several watersheds and vice versa. The watershed and topographic data will aid in giving a preliminary understanding of groundwater flow direction, gradient and groundwater divides. Aquifer boundaries can be groundwater divides or geologic contacts representing contrasts in permeability.

> Between 2000 and the present, the Ontario Government invested $19.3 million to support groundwater dependent communities to map municipal wellhead protection areas using sophisticated models, and to map regional groundwater conditions and aquifer vulnerability. The studies will provide valuable information that will help the communities develop local source protection measures, and will support the development of a province-wide source water-protection framework. By the Spring 2004, over 95% of Ontario communities that rely on ground water will have a common base of information on their groundwater.

Figure 6.4 shows an example of a watershed delineation map, overlaid with indications of land-uses.

Figure 6.4 Generalized land-use overlay with watershed delineation map



One of the fundamental concepts of wellhead protection studies is the clear identification of the area(s) to be protected. Fundamentally, the area of lands which will likely contribute recharge to the well needs to be established or "delineated." However, the actual delineation process can be based on a analysis of a number of criteria and criteria thresholds and the application of any one or more of a number of delineation methods. The criteria and thresholds define the technical basis for delineation of protection areas. The delineation methods apply the criteria in that they are used to develop the protection area boundaries.

Several options are available for delineating wellhead protection areas. These range in complexity from simple mapping techniques requiring minimal geological knowledge to complex mathematical models requiring significant amounts of field data. The decision on what type of delineation method to use needs to be based on the aquifer characteristics and the relative risks of contamination. More sophisticated groundwater modelling may be extremely useful in areas with several potential sources of contamination to a drinking water well source.

METHODS FOR DELINEATING WELLHEAD PROTECTION AREAS

Establishing an **arbitrary fixed radius (AFR) protection area** is as simple as drawing a radius around each wellhead in the watershed/aquifer on a topographic map. In British Columbia, the zone of protection is usually set at a distance of 300 m around the wellhead. This distance protects against immediate threats to groundwater sources and minimizes difficulties in managing the land within the protection zone (Government of British Columbia 2000). This method should only be used as a temporary measure until other hydrogeologic information for the watershed/aquifer becomes available.

The **calculated fixed radius (CFR)** method uses a simple algebraic formula for readily available wellhead data, and provides a greater level of precision for estimating the amount of area needed to protect against contamination events. The CFR represents the amount of time required for a contaminant at the outer boundary to reach the drinking water well, and is usually based on one, five, and ten-year times of travel (Government of British Columbia 2000).

While both the AFR and CFR delineation techniques can be used for sand and gravel aquifers where the water table is relatively level and wells supply no more than 100 connections, it is necessary to define a zone of capture in watershed/aquifers with sloping water tables (Government of British Columbia 2000). When groundwater recharge comes from 'up-gradient' sources, the capture zone will have an elongated, parabolic shape rather than circular shape.

6.1.2 Inventory of Land-use and Contaminants

In the next step of the assessment, contaminants that may be of concern to a water supply should be identified, along with their sources. Typical methods used for identification include:

- Inventory of land uses
- Inventory contaminants sources
- An evaluation of watershed/aquifer characteristics
- An evaluation of source water quality monitoring data

> **Potential Sources of Drinking Water Contamination Index**
>
> The type of land use within a watershed may help in identifying the potential hazards to source waters. Land use inventories involve identifying the land uses within an area and then inferring the nature of the potential hazards associated with each type of land use. The EPA has provided a resource guide for creating such an inventory list. The presence of the identified land use does not necessitate the presence of the associated hazards, nor does include other potential hazards from existing and non-identified land uses. The resource guide can be accessed through the following link:
>
> www.epa.gov/OGWDW/swp/sources1.html

The level of effort expended on identifying contaminants of concern will depend on available resources. However, the common goal of all inventories is to gather existing data on contaminant sources and levels, and fill any knowledge gaps with new information from public consultations or field surveys.

Creating an inventory of specific types of threats that may reasonably be expected to occur within the watershed/aquifer is an essential component of a source water protection plan, as the nature of the hazard will influence the type of treatment as well as the watershed/aquifer management response required. Most threats to source waters are the result of human activities within the watershed/aquifer. For example, a watershed where the primary contaminant of concern comes from industrial effluent will be managed differently than one where the main threat to source waters is nutrient enrichment.

An inventory of the likely contaminants that may be found in source waters is shown in Appendix C.

A few of the common approaches that can be used to identify potential threats to a water source are outlined below.

Land-use Inventories

The nature and extent of different land uses are crucial features to investigate in a watershed/aquifer assessment, as land use will determine the presence or absence of threats to source water quality from human activities.

Land-use change is often the primary cause of water quality and habitat degradation in a watershed/aquifer. Knowledge of the type of land use within an area can help identify the potential threats to source water. Land use inventories involve identifying the land uses within an area, and then inferring the nature of the potential contaminants associated with each type of land use. Land use inventories should identify the types and percentages of each land use in the watershed/aquifer and note the types of contaminants associated with each type of land use.

It is also important for an attempt to be made to quantify the presence of human activities that could potentially alter drainage patterns within the watershed/aquifer. For instance, the construction of impermeable features such as roadways will change the drainage and infiltration patterns of the watershed/aquifer by increasing surface runoff while reducing groundwater infiltration. The Atlas of Canada is an interactive mapping website that provides regional information on a variety of environmentally sensitive variables, including road density (NRC 2002b).

Information on land-use within a watershed/aquifer can be obtained from a variety of sources including aerial photographs, municipal zoning maps and area maps. These information sources are available from the municipal or provincial government offices. Land use inventory maps for rural Canada are available from Natural Resources Canada on-line (NRC 2000).

Lands used for agricultural crop production can result in non-point source inputs of pesticides and nutrients from leaching and/or surface runoff. In areas where livestock operations occur, the primary threats to water quality could be contamination from nutrients and microorganisms.

In urban areas, the pollution threats will vary depending on the specific localized land use (*e.g.*, parkland, stormwater retention pond, and commercial zones).

Industrial land uses will present threats of contamination from effluent releases, groundwater infiltration, and overland water flow. Industrial contaminants could include organic chemicals, metals and nutrients.

Residential areas can result in contamination threats from runoff of domestic chemicals, such as pesticides and fertilizers, or nutrient enrichment from sewage disposal.

Maps can be used as an initial screening tool for potential threats by overlaying major land uses in the watershed/aquifer in relation to source water locations. This type of exercise can be conducted from municipal records, such as land titles, developmental zoning records and aerial photos, and therefore may not require field surveys. This process serves as a first step in conducting a contaminant inventory, as it allows managers to focus future efforts on high-risk areas.

Note: Maps can also be found through the appropriate provincial government department(s).

Contaminant Source Inventories

Although land use inventory maps can indicate which groups of hazards are expected in a given area, it is often necessary to identify and inventory the specific sources of contaminants within each land use area. This involves identifying point and non-point sources of potential contaminants within the watershed/aquifer as well as factors that can influence downstream water quality.

Discharges from point sources are often regulated through provincial/territorial licenses or permits. Furthermore, information on current discharge activities can be obtained from conducting site surveys, or by soliciting information from industries, agricultural producers, and municipal operators in the watershed/aquifer using questionnaires and interviews. Although conducting interviews and using questionnaires saves a great deal of time and resources, special attention needs to be paid to the accuracy and completeness of responses.

Government records can assist in identification of point source effluent discharges and the associated contaminants of concern.

The National Pollutant Release Inventory (NPRI) of Environment Canada maintains an on-line, publicly-accessible database of pollution discharge data for companies releasing specified amounts of NPRI-listed substances annually: http://www.ec.gc.ca/pdb/npri

Non-point sources are threats caused by surface runoff, leaching and atmospheric deposition of contaminant sources. Because non-point source pollution is hard to identify, the factors contributing to non-point source pollution may need to be inferred based on the surrounding land use.

Evaluation of Watershed/aquifer Characteristics

Watershed/aquifer characteristics influence drinking water source quality, and therefore need to be considered when identifying potential contaminants in a watershed/aquifer area. Factors such as population levels and land-use patterns will strongly influence the quality of downstream receiving waters, as well as groundwater. However, it is also important to collect information on other watershed/aquifer characteristics, such as climate, topography, wildlife, vegetation, and geophysical aspects. The watershed/aquifer characterization process is not intended to be a massive data collection exercise in its own right, but rather serve to provide the appropriate level of detail to allow for the effective management of multiple source water protection barriers.

Spatial variability in watershed characteristics, and their resulting influences on source waters, are more easily understood and communicated in a visual format.

Geographic Information System (GIS) technology is a useful tool in preparing a watershed characterization. The watershed characteristics, their variations across space, and their relation to one another can be easily displayed in a map, or database formats using this technique. GIS allows several 'layers' of data to be overlaid on top of each other in a single topographic map, allowing multiple watershed characteristics (and their interrelationships) to be viewed simultaneously.

Population

Population data can be used as an indication of the amount of human influence within the watershed/aquifer. Human influences present one of the highest potential risks to water quality within a watershed/aquifer, making examinations of population trends within the watershed/aquifer an important component of characterizing the risk to the watershed/aquifer.

Data collection should focus on population size, density and spatial distribution within the watershed/aquifer. A dense population can have a direct impact on water quality through nutrient loading into the watershed/aquifer system from wastewater or through other releases of pollutants. Other population statistics that may influence water quality such as growth rate and population trends may also be considered in the assessment. Statistics Canada provides national population and census information on-line (Statistics Canada 2002). Provincial or territorial departments of health or vital statistics are also a good source of current information.

Climate

Climate can influence both the quantity and quality of water in the watershed/aquifer. Climate determines the amount of water recharged into the watershed/aquifer via precipitation, the amount of precipitation lost to evaporation and the timing of low and high stream flow periods. It indirectly influences the amount of infiltration or surface runoff. Descriptions of watershed/aquifer climate should identify the annual and monthly precipitation amounts and the types of precipitation, the mean annual average temperature and monthly mean temperatures, the temperature range, the annual and monthly humidity, the average date of spring runoff, and the likely occurrence of unusual events such as storms or blizzards. Any other distinct climate characteristics should also be noted. If the watershed/aquifer is large or the climate is expected to vary widely over the area (*i.e.,* from low to high elevations in a mountainous terrain), the change in climate should be noted.

> Climate data *for numerous weather monitoring stations across Canada is available on the Internet.*
>
> A summary of available Prairie Province Water Board Reports including reports related to precipitation and streamflow, runoff distribution and variability and other topics are available from Environment Canada (2002b).
>
> The Geoconnections Discovery Portal (NRC 2002a) also provides links to climate data in GIS format.

Seasonal variations of water quality due to a variety of natural and human influences should also be noted. Human activities can result in seasonal fluctuations in water quality, such as seasonal run-off of agricultural manure, fertilizers and pesticides that can result in impaired water quality. Other seasonal variations that can impact source water quality include:

- **High ambient temperatures.** Higher ambient temperatures in summer can simulate algal growth in source waters, which in turn can deplete oxygen in source waters and increase total suspended solids (eutrophication).
- **Spring runoff.** Higher runoff flows caused by spring melt or heavier periods of rain can increase stream flow and elevate the stage of a water body, resulting in increased erosion and elevated suspended solids/turbidity in source waters.
- **Low flow conditions.** Watersheds in late summer periods in drier years can experience significant reductions in streamflow. Reduced flow results in corresponding reduced assimilative capacities for a water source. As flows decrease, point source discharges are not diluted

adequately, resulting in higher pollutant concentrations in source waters.

- **Recreational use**. Depending on the accessibility and size of the source water body, the summer recreational season may bring increased recreational use in desirable areas of a watershed/aquifer. Recreational boat traffic and inefficient small engine personal watercraft can cause increased erosion, and elevated levels of pollutants from boat motors.

Seasonal water quality data is available from provincial government offices.

> Topographical maps, aerial photographs and other topographic data are available from the Provincial government natural resources offices. Internet links to a wide range of GIS data, including topographic maps, can be found at the Geoconnections Discovery Portal (NRC 2002a), and from the Habitat and Enhancement Branch of the Department of Fisheries and Oceans (DFO 2002).

Topography

Elevation contours used to delineate between watersheds and sub-basins within a watershed are also used to determine slope gradients. Areas of steep slope gradient are expected to have more surface water runoff than areas of low slope gradient, and therefore carry a greater risk for sediment deposition from erosion into stream channels.

Geological Characteristics

Geological characteristics of the watershed/aquifer (*e.g.* bedrock and surficial geology, and soils) may influence groundwater and surface water chemistry, and watershed/aquifer drainage patterns. The watershed/aquifer characterization should identify soil types, textures and drainage patterns. Soil texture influences whether precipitation is likely to infiltrate or run off, and whether sediment will be eroded from the soil. A sandy textured, well-drained soil would be expected to have a higher infiltration capacity than a poorly drained clay soil. Likewise, a sandy textured soil with low organic matter content would be expected to be more susceptible to erosion than a clay soil with a high organic matter content.

> Information about bedrock and surficial geology are generally available from the natural resources department of provincial governments.
>
> Soil survey maps are usually available from provincial agriculture departments.
>
> Maps and GIS data for major drainage systems in the Prairie Provinces are available from Agriculture and Agri-Food Canada (AAFC 2002). Geological GIS data is also available at the Geoconnections Discovery Portal (NRC 2002a).

Examinations of watershed/aquifer geology should note the major geologic formations, their modes of deposition and their mineralogy. The geologic formations surrounding major aquifers and aquitards will influence groundwater movement throughout the watershed/aquifer and should therefore be carefully examined to identify the likely paths of groundwater movement. The mineralogical composition of the watershed/aquifer geology, and the weathering processes, will determine which chemicals dissolve in water. The nature of the geology of the area will affect sediment transport to source waters. Examinations of watershed/aquifer geology can be used to identify vulnerability to erosion, mass wasting and other degradative processes.

Aquatic Life, Wildlife and Vegetation

Watershed/aquifer health is reflected in the abundance and diversity of flora and fauna in the ecosystem. As a result, watershed/aquifer categorization needs to identify the major terrestrial and aquatic species and their habitats.

The health of aquatic life can give an indication of water quality in an area and should therefore be noted. The presence of stressed aquatic life can be an indication of poor water quality such as low dissolved oxygen or high concentrations of contaminants.

Major recent changes in watershed/aquifer vegetation should also be noted. For example, forest fires or changes in human land-use activities may result in a change in species composition. Particular attention should be paid to the alteration of watershed/aquifer vegetation that may negatively impact source water quality, especially in wetland and riparian areas.

> **Data on vegetation in the watershed** can be obtained from land-use inventories, habitat and vegetation surveys, and examination of aerial photographs (for general ecosystem identification).
>
> **Links to forestry GIS data** in Canada can be found at Natural Resources Canada's Geoconnections Discovery Portal (NRC 2002a).
>
> **Land capabilities for forestry in rural Canada** are available from the Canadian Land Inventory (NRC 2000).
>
> **Other information on local vegetation** is available from the natural resources departments of the appropriate provincial government.

Terrestrial vegetation, such as plants and trees and submerged aquatic vegetation all play a role in protecting source waters. Vegetation can directly influence water quality by acting as a sediment barrier and/or biofilter for nutrients and contaminants that would otherwise reach source waters. Due to the importance of vegetation in sustaining the viability of the watershed/aquifer, the characterization needs to include a description of the dominant vegetation types in each ecosystem (*i.e.* forest, riparian, wetland, aquatic, etc.), what percentage of the watershed/aquifer is composed of each ecosystem, along with the floral species composition and the community structure within each ecosystem.

Evaluation of Source Water Quality Data

Contaminant inventories can also be compiled by collecting historical and current water quality data in the watershed/aquifer if available. Spatial and temporal patterns (*e.g.,* to include daily, seasonal, and annual changes) should also be examined as part of the assessment. These offer the advantage of providing quantifiable estimates of contaminant loads to specific source waters. However, relying solely on water quality surveys without prior knowledge of potential contaminants within the watershed/aquifer may result in the lack of detection of some contaminants.

Some of the key steps involved in implementing a source water quality monitoring program are:

- Reviewing the existing data against environmental quality objectives, or by statistically analyzing data to look for trends or differences between regions. Currently, procedures for establishing EQOs for microbiological parameters in Canada are not standardized. Ideally, microbiological pathogen concentrations in source waters would be monitored, and the results submitted to the treatment operators.
- Identifying gaps in the data that did not allow for thorough assessment
- Developing a long-term plan to fill missing data gaps, which can then be used for source water assessments, or water quality modeling.
- Discussing how coordination of monitoring activities from various stakeholders or government agencies can allow for an effective future monitoring program (see section on TQM Source Water Monitoring).

6.1.3 Vulnerability Assessment and Ranking

For general information on how to determine levels of risk, see Section 4.

Once the hazards within a watershed/aquifer have been identified through the processes discussed above, it is necessary to determine the vulnerability of the watershed/aquifer to the identified hazards and to assess their potential impact on human health. The results will guide watershed/aquifer protection efforts and help determine the type of treatment required to render the water safe for drinking. It is important to identify the risk to the source waters from each threat in the watershed/aquifer.

The assessor (*e.g.,* system owners and operators) is concerned about:

- The quality of the source water as it influences the nature of the treatment process required to reduce the potential health risk and produce safe and aesthetically pleasing water at the consumers' tap
- The quantity, reliability, vulnerability, quality (including seasonal variability) and potential for future degradation of the quality

The assessor now needs to determine the risk to the source waters from each threat in the watershed/aquifer prior to taking action on the design of a water treatment system and watershed/aquifer protection measures.

In assessing vulnerability or risk, the data from the hazard identification process needs to be complemented with monitoring data to get an idea of the concentration at which the chemical/physical parameter or microorganism is found in the source water and whether the concentration fluctuates over time. This type of data is gathered through long-term monitoring programs (see Section 8.1). Concentrations can be modeled (see Section 6.2.2) with such data as land-use information, watershed hydrogeological and soil characteristics and, toxic substance physico-chemical properties, however, it is preferable to obtain real monitoring data at the site-specific level.

In cases where hazards can be defined numerically (*e.g.*, concentration of a toxic substance), the risk is a quotient between exposure and hazard. Therefore a quotient that is greater than "one" would signify a positive likelihood that an effect may be observed. For the purposes of this section, the hazard will be defined as a low threshold effects concentration to be represented by an environmental quality objective (EQOs) (see below). EQOs are often water quality guidelines (*e.g.,* source water quality guidelines), objectives or standards set out by most provinces and territories or by Federal/ Provincial/Territorial committees (see Section 3.4).

Setting Environmental Quality Objectives (EQOs)

Deciding on which EQOs are to be met for drinking water sources is the responsibility of the authority governing watersheds and/or aquifers (see Sections 3 and 6.2). Utility owners and other stakeholders may be asked for their input. EQOs based on the protection of aquatic organisms alone may be too conservative, given that the majority of source waters will undergo some form of treatment prior to distribution for human consumption. As an example, in their source to tap approach for protecting public drinking water sources, the province of Newfoundland and Labrador has adopted the *Guidelines for Canadian Drinking Water Quality*. These are not used as source water guidelines *per se*, but rather as reference values to indicate the extent of treatment required to meet tap water standards, especially for microbiological parameters (Government of Newfoundland and Labrador 2001). This practice, however, has not been adopted in other jurisdictions.

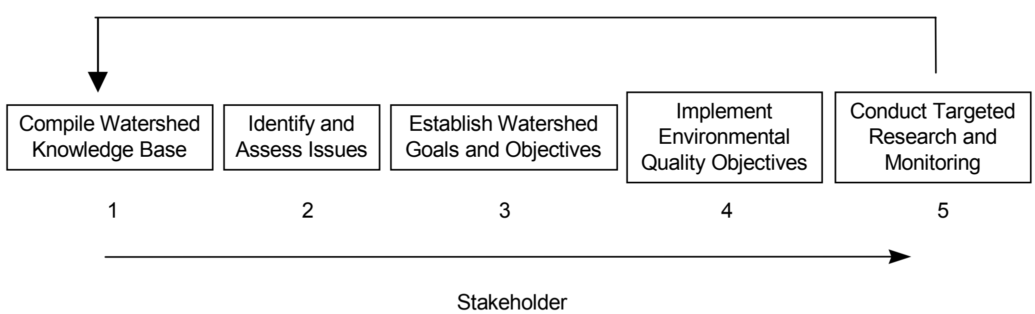
Environmental Quality Objectives (EQOs) are established limits or thresholds of biological and/or chemical contaminants in water set by watershed/aquifer committees or other governing bodies in order to ensure sustained protection of source waters for drinking water. EQOs may be narratives or numerical limits. The premise for setting EQOs is that they are relevant, economically and technically feasible and easily understood by risk assessors and managers.

To be relevant in the risk management process for the protection of public health (see Section 2), EQOs should be set for hazards in source waters that are linked to hazards in the water supply system (*e.g.*, turbidity, total organic carbon, microbiological pathogens). Only then will mitigative efforts to curtail hazards in source waters contribute to the overall reduction of risk to human health.

When ambient contaminant levels are consistently below provincial guidelines, several options are available for setting site-specific EQOs. Objectives can be adjusted downwards or upwards to some point below or above the provincial guideline to account for site-specific physico-chemical properties, or sensitive species, which may be endemic to those waters but were not represented in the original toxicological screening process for deriving the guideline. These site-specific objectives (SSOs) can be set at the background levels to reflect good water quality, thereby preventing any further deterioration. This decision is often based more on public perception than any scientific justification for reducing the values. That said, it is important that high quality water not be degraded to the level set by an EQO or SSO if the water is of better quality to begin with. A CCME guidance document on deriving SSOs is now available to water managers (MacDonald et al. 2002). Finally, if there are no site-specific modifying factors that may alter toxic responses in resident biota, or humans, then the established guideline thresholds may be used and the ambient levels can simply be accepted as non-threats. Figure 6.5 shows a framework for using EQOs in a source water protection program.

In the event that ambient levels are consistently higher than provincial guidelines it will be necessary to determine if there is a risk to public health. If there is, the governing body or the authorities may need to try to find the sources of the contaminant. If there are no loading sources from human activities in the watershed/aquifer, ambient levels will likely reflect natural background levels. In this instance, water authorities may want to establish SSOs for this compound at the ambient levels. If there are known loading sources of the parameter(s) exceeding provincial guidelines, watershed/aquifer loading models may need to be used to determine the extent of the impact from discharge sources, and therefore determine the potential for corrective measures (*i.e.,* load reductions) to reduce ambient levels.

Figure 6.5 Framework for Using EQOs in a Source Water Protection Program



Approaches that incorporate the use of environmental quality objectives in risk determinations and ranking techniques are discussed below.

Ranking Schemes

The processes discussed thus far for source water assessment and setting EQOs for a source water body allow water managers to make an informed assessment of the risks associated with each of the contaminants present. The level of detail required in a risk assessment will likely increase with demands placed on a given drinking water source. It is important to keep in mind, however, that the primary purpose of a risk assessment is to provide water managers and stakeholders with the required information they need to prioritize protection efforts for contaminants found in the watershed/aquifer.

In its most basic form, a risk assessment can simply be a ranking of hazards against designated benchmarks for the protection of the health of consumers. In the example in Table 6.1, two options would be available for ranking the risks associated with these contaminants of concern: those parameters that exceeded the EQO by the greatest magnitude could represent the greatest risk, and can be ranked according to their maximum exceedence ratio; alternatively, parameters which have frequently exceeded the EQO could exhibit the greatest risk.

In some instances, the relative risk provided by these ranking schemes can be misleading, and should be properly interpreted. For example, the risk provided by a contaminant slightly exceeding its EQO could far outweigh the risk of another contaminant far exceeding its EQO. Decision rules can be established whereby the top-ranking risks from both categories are given a high priority for protection measures. The outcome of the ranking will also aid in determining the effectiveness and level of treatment required.

Table 6.1 Sample risk assessment ranking scheme based on measured water quality variables and established environmental quality objectives

Parameter of concern	Environmental Quality Objective[1] (mg/L)	Maximum concentration found (mg/L)	Maximum exceedence ratio	Ranking (A)	Total no. of EQO exceedences per year	Ranking (B)
Parameter A	0.025	0.035	1.4	4	1	4
Parameter B	0.005	0.020	4	2	5	2
Parameter C	45	80	1.8	3	15	1
Parameter D	0.05	0.02	0.4	5	0	5
Parameter E	1	12	12	1	2	3

It is also possible to rank the vulnerability of source waters themselves rather than the dangers associated with a particular contaminant. For the use of groundwater sources, there are a number of methods that can be used to assess the vulnerability of aquifers to potential contamination from the soil surface. These include DRASTIC, and the Ontario Ministry of the Environment's Aquatic Vulnerability Index (AVI).

DRASTIC is an acronym based on seven parameters which all are evaluated and given a value from 0 to 10:

D: Depth to water table
R: Recharge
A: Aquifer media
S: Soil media
T: Topography
I: Impact of vadose zone
C: Conductivity

These scores are then added to obtain an index value. High values indicate higher risks of contamination of groundwater sources. The index approach makes it possible to then rank the relative vulnerability of selected aquifers (or regions of the aquifer) within a watershed.

A risk assessment may also categorize, rather than rank, relative hazards within the watershed/aquifer. In the watershed management plan for the City of Rossland, British Columbia, each potential chemical and microbial threat to source water quality was rated according to:

Hazard: The likelihood that the process or activity will release contaminants

- Rated: *low* (L), *moderate* (M), or *high* (H)

Susceptibility: The consequence to the water source if the activity/process does release contaminants. Related to the proximity of the activity/process to the source water (see Figure 3.15 for sample susceptibility determination)

- Rated: *low* (L), *moderate* (M), or *high* (H)

Risk: The product of Hazard and Susceptibility defined as the risk of the water source being contaminated by the specified activity/process

- Rated: *low* (L), *moderate* (M), *high* (H), or *very high* (VH)

(Dobson Engineering 2002)

Table 6.2 provides an example output table for this type of risk assessment. A separate table should be completed for each watershed/aquifer, or sub-watershed contributing to the source water supply. The level of detail included for the processes/activities will likely vary between SWP programs, depending on the resources available for the assessment.

Table 6.2 Sample risk assessment categorization scheme for processes and activities at the watershed level.

Process/Activity	Hazard	Susceptibility	Risk	Comments
Natural erosion, landslides	M	M	M	Some steep and potentially unstable terrain
Timber harvesting	L	L	L	Some satisfactorily restocked cutblocks in upper watershed; roads in various states of deactivation
Roads/utilities	H	H	VH	Highway x parallels creek; city roads in western portion; natural gas pipeline intersects lower watershed
Other land use	H	M	H	Industrial parks, auto wrecker, cemetery located within watershed

(adapted from Dobson Engineering 2002)

In summary, this section described methods for conducting a source water vulnerability assessment and ranking risks. System owners and operators can now either use this information to design, evaluate or upgrade a water treatment system (go to Section 7) or to take steps to ensure the long-term protection of their source water through their involvement in the development of watershed/aquifer management plan (continue below).

6.2 Watershed/Aquifer Management Plan

The purpose of a watershed/aquifer management plan is to implement management actions that serve to maintain or improve the quality of source waters. Once treated, these waters will provide clean, safe, and reliable drinking water over the long-term. Focusing on water quality for drinking water is a good mechanism for creating common ground among stakeholders who may have conflicting uses for the water in the watershed/aquifer. At the municipal level, watershed/aquifer management planning goes hand-in-hand with land-use planning.

The development of a watershed/aquifer management plan entails evaluating management options based on the ranked hazards identified in the source assessment, prioritizing actions, implementing them to maintain or improve source water quality and evaluating their efficiency over the long term.

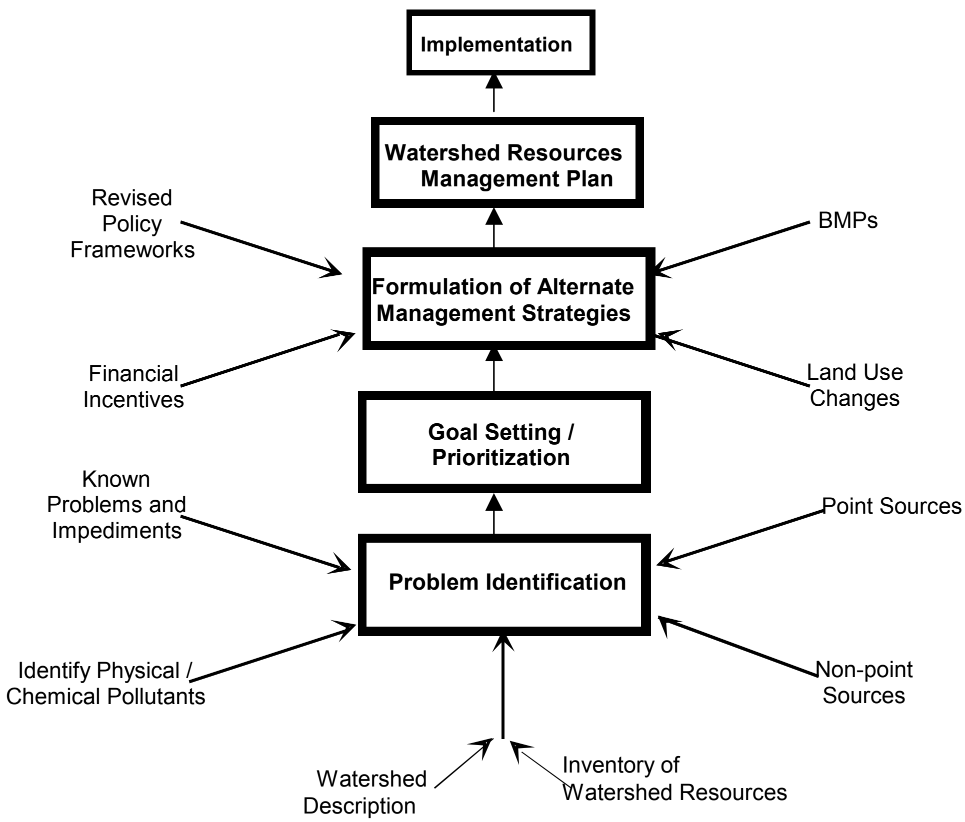
The watershed/aquifer plan is an innovative management process that examines all factors affecting the entire watershed (such as air, land, and water resources) while focusing on the highest priority problems. The approach involves all stakeholders in the planning, decision-making, and implementation processes, including First Nations peoples, private institutions, public institutions, government agencies, environmental groups, and the public.

Membership in a Source Water Protection Committee should reflect as many of the interest groups as possible, and could include technical persons who can offer expertise in support of watershed protection initiatives, such as:

- Water department/utilities staff
- Planning /zoning department staff
- University professors/science teachers
- Conservation groups
- Chamber of commerce members
- Financial/lending institutions
- Elected officials
- Industrial managers/agricultural sector
- Residents of the watershed

A watershed/aquifer plan reconfirms the choice of Environmental Quality Objectives (EQOs) that were chosen in the source water assessment (see Section 6.1) as the management targets or goals against which management actions will be evaluated. In the risk management process and overall reduction of risk, EQOs should be set for hazards in source waters that are relevant to those in the water supply system (*e.g.*, turbidity, total organic carbon, microbiological pathogens).

Figure 6.6 Watershed Committee Action Process



6.2.1 Management Process

It may be useful for a Source Water Protection (SWP) committee to oversee both the source water assessment (see Section 6.1) and the watershed/aquifer management plan. It is important for such a committee to partner with stakeholders outside of its circle to access further resources (human and financial) and to obtain community acceptance. The committee should have a mandate, terms of reference and a decision-making process. An example of a committee action process is shown in Figure 6.6.

SWP committees can balance potentially competing interests for source water uses within a watershed/aquifer. These committees can facilitate dialogue and long-term relationships between the various watershed/aquifer residents and/or users. A SWP committee is composed of all stakeholder groups or individuals that use the water resources, including recreational, private and public users, and municipal and private owners of public drinking water distribution systems. It is important for all interested parties to be committed to developing a local watershed/aquifer management plan to protect and sustain a clean, safe, and secure drinking water supply.

Some organizations and individuals will have competing interests in water uses, and will therefore champion their own interests. For this reason, it is important to provide a balanced committee that is not unduly weighted by any one interest sector. A further complication is that watersheds/aquifers can potentially cross municipal, provincial and even national boundaries. Productive SWP committees require effective partnerships that focus on common interests, respecting viewpoints from all participants and remain manageable in size (US EPA 1997a).

It is important for membership in the SWP committee to be long-term. Effective management and protection of the watershed/aquifer requires long-term planning and therefore needs stability and consistency in committee membership. It may be beneficial to raise both the profile and prestige associated with actually participating on an SWP committee whose purpose is ultimately the sustainability of the local ecosystem and the preservation of public health. Participants on the committee need to encourage the creation and continuation of dialogue on

Role of Municipalities in Source Water Protection Planning

As some watersheds may be partially or wholly contained within municipal boundaries, municipalities may have a direct effect on protection measures. Municipalities may be aware of the specific concerns of their communities and able to foster community involvement and ownership in water protection issues.

Implementation of measures at the municipal level can provide groundwork for further involvement from other entities. It is key for municipalities share their experiences and issues with other municipalities and other stakeholders. For more information, see the FCM document in the appendices.

watershed/aquifer issues and active, collaborative decision-making by all participants. **Successful partnerships take time to develop**.

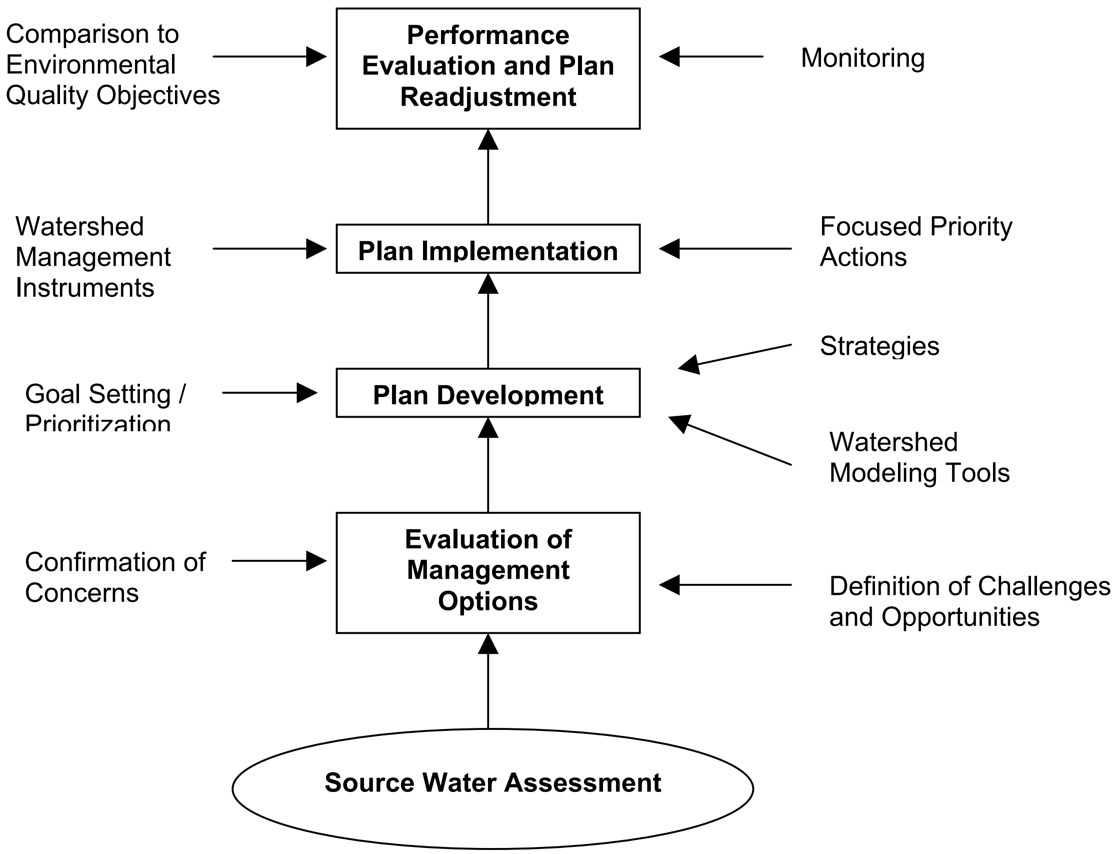
6.2.2 Management Activities

During the planning process, stakeholders confirm issues of concern within the watershed/aquifer and set priority management needs and are involved in negotiating resolutions to conflicting land-use within the watershed/aquifer and develop consensus-based strategies. All stakeholders will be involved in implementing the source water protection plan. Government agencies may be required to ensure land-use activities in the watershed/aquifer are consistent with the plan. Governments may also provide technical assistance in implementation. Other stakeholders may be involved in other capacities, for example, non-profit conservation groups may be involved in watershed/aquifer restoration activities.

As shown in figure 6.7, the plan development process is a four-stage process:

1. **Evaluation of management options from source water assessment results**. This includes confirming concerns and objectives, defining challenges/opportunities
2. **Developing the protection plan**. This includes setting management action priorities, negotiations and developing strategies for addressing concerns and achieving objectives.
3. **Implementing the plan.** This includes mobilizing resources and taking focused actions on priority issues using watershed/aquifer management instruments.
4. **Performance evaluation and plan readjustment.** This involves comparing monitoring data to EQOs, reassessing management actions and/or EQOs and make the improvements where necessary.

Figure 6.7 Watershed / Aquifer Management Process



6.2.3 Evaluation of management options

This step consists of evaluating concerns and objectives determined in the source water assessment and valued features of the watershed/aquifer (*e.g.*, landscape traits, annual spawning run, old growth forests). The purpose of the evaluation is to ensure the accuracy and comprehensiveness of the problem definition, and that this is well understood by stakeholders. It is important to consider concerns combining water and other natural resources issues, regulatory requirements, local economy, and social matters, whether factual or perceived.

During the source water assessment (see Section 5.1), several features of the source water area were identified that are especially valuable ecologically, economically or socially, and help maintain or improve source water quality which once treated, will ensure clean, safe, and reliable drinking water over the long-term. These valued features need to be weighed against the problems and concerns (noted above) with providing good source waters. The risk of negative impacts upon a valued feature of the watershed/aquifer is a good basis for evaluating the concerns and setting priorities for action.

At this stage, it is important for stakeholders to identify potential challenges and opportunities. Challenges may be scientific or socio-economic. Scientific challenges pertain to filling scientific data gaps that address uncertainties in the science. Socio-economic challenges are those that impact the livelihood of communities in the watershed/aquifer area. Opportunities are, for example, the creation of partnerships among stakeholders leading to good communication and coordination/consolidation of efforts (*e.g.*, data-sharing). This promotes a sustainable use of the shared resource.

6.2.4 Developing the protection plan

By this stage, all stakeholders will have provided some input on the concerns (during the evaluation process discussed above). It is important for priorities to be established in order to focus resources and efforts on mitigating risks to source water quality. Priority-setting may be guided by the following set of principles:

- **Focus on water quality for drinking water:** This is a good mechanism for creating common ground among stakeholders who may have conflicting uses for the water in the watershed/aquifer.
- **Principle of Protecting Water Systems**: Watershed/aquifer systems such as streams, springs, groundwater, lakes and related riparian systems are recognized as valuable natural features requiring protection. Restoration of degraded ecosystems back to their functional character should be attempted where possible.
- **Ecosystem Principle**: The interconnection of the environment is a fundamental principle of watershed/aquifer planning. A

Source Water Protection plan will promote the watershed/aquifer area as the basis of sound environmental planning and management of water resources. (CCME 1996)

- **Innovative Technology Applications**: New approaches/technologies that address watershed/aquifer management needs and administrative requirements should be encouraged.
- **Proactive Management**: Cost-effective, proactive, and preventative management of watershed/aquifer assets should be favoured over cost-intensive, reactive watershed/aquifer management.
- **Economic Considerations**: Short and long-term economic considerations should be considered.
- **Land Owner Rights, Privileges, and Responsibilities**: Societal and individual rights, privileges and responsibilities should be recognized throughout the watershed/aquifer planning process.
- **Consultation**: When undertaking watershed/aquifer resource management actions, direct consultation between government agencies, municipalities, and public stakeholders is important.
- **Fair and Equitable Considerations**: Social, economic, and ecological considerations associated with watershed/aquifer protection planning need to be applied with fairness and equity.
- **Education**: Sharing and communicating watershed/aquifer protection information and watershed/aquifer characteristics is essential to develop community awareness that in turn fosters informed decision-making processes.

Using these principles, a targeted watershed/aquifer approach is an effective means by which to direct available resources to areas within the watershed/aquifer where public health benefits can be realized. In the assessment process, vulnerable zones within the watershed/aquifer should be identified, leading to the assignment of high priority to vulnerable areas in the targeted watershed/aquifer approach. In some situations, a vulnerable zone may require aggressive protection, such as required land use restrictions. Prioritizing using a targeted approach includes the following:

- Identifying watershed/aquifer zones with the most critical water quality problems and directing programs and resources to the solution of these problems.
- Directing programs and resources to watershed/aquifer zones with the highest potential for improvement.
- Protecting existing high quality water resources from future impairment through a preventative approach to water quality management.
- Identifying watershed/aquifer zones where there is a need to coordinate multiple remedial/protective priorities.

Stakeholders need to work together to obtain consensus on prioritizing, including determining which problems/opportunities to pursue and in what order.

Often it is beneficial to categorize watershed protection efforts into several main protection areas such as streams with point source concerns, streams with non-point source concerns, lakes; and groundwater. Within these main areas, issues identified can be further prioritized on the basis of both preventative and restorative measures.

- Preventative Measures are selected to ensure existing high quality source waters are protected such as highly desirable biological habitat sources and other provincially protected water sources identified as habitat for endangered species, and streams used as a source for drinking water.

- Restorative Measures are selected to identify the most critical source waters in need of remedial action in order to achieve water quality objectives and attain full use of their established designated uses.

Proposed measures should directly or indirectly mitigate the impact or reduce the contaminant (chemical or biological) load of concern. The plan should include components such as actions and contingencies, costs and incentives, roles and responsibilities, an implementation schedule, implementation guidance and an evaluation / performance step (see Figure 6.7).

Tools for Developing the Watershed/Aquifer Management Plan

Many predictive models are available to stakeholders active in the development of watershed/aquifer management plans and are discussed below.

Surface Water Models

When combined with good monitoring datasets, properly calibrated, tested, and verified hydrologic models provide extremely powerful water assessment tools. The models offer insight into impacts associated with known and anticipated land use activities within the watershed/aquifer, which can provide valuable forecasting information for assisting with management plan development and management actions.

Although hydrological modelling may be the preferred option, many system owners and communities may not have the financial resources to undertake such a program. In these cases, it is important to gather as much information on flow patterns and the potential risks as available to assist in the development of a plan. In these types of cases, a checklist should be developed to ensure all risks are identified and, where possible, appropriate management practices are implemented.

Watershed-scale models are specifically used to simulate and predict localized pollutant loading, transport, and transformation. There are three major types of watershed-scale models that can be used in the development of a Source Water Protection plan:

- **Loading models** predict the transport of pollutants from watershed/aquifer sources to the receiving waters

> More Information on Models
>
> For detailed information about specific models available and their uses, check out the following websites:
>
> US EPA: www.epa.gov/waterscience/wqm and www.epa.gov/ada/csmos/models.html (Groundwater Models)
>
> Surface Water and Water Quality Models Information Clearinghouse: http://smig.usgs.gov/SMIC
>
> US Army Corps of Engineers: www.wes.army.mil/el/elmodels
>
> Natural Resources Conservation Service (US Department of Agriculture): www.wcc.nrcs.usda.gov/water/quality/frame/waterqal.html

- **Receiving water models** predict the transport and transformation of pollutants through water bodies such as rivers, lakes and streams
- **Integrated models** combine models and data with a convenient user interface that can be used to create GIS-based spatial representations of model outputs.

Groundwater Models

Several methods are available to delineate wellhead protection areas. Computer models can be valuable tools in the development of wellhead protection plans. A variety of software is available that will model groundwater flow and contaminant transport. Each of the flow and transport models is based on governing equations that are specific to the intent of the model. These equations can be resolved either analytically or numerically.

Analytical models use exact closed form solutions of the appropriate differential equations. The solutions are continuous in time and space. Although analytical models provide exact solutions, they use many simplifying assumptions. When the system being modelled is simple, reasonable estimates of groundwater flow can be attained. However, these types of models have limitations with complex flow systems as well as with temporal or spatial variations in the system.

Numerical models can simulate the three dimensional boundaries of an aquifer using numerical equations. Numerical models can be expensive and they do require a detailed dataset that accurately characterizes the source aquifer. Numerical modelling provides the most scientifically defensible basis of calculating groundwater flow based protection zones, provided they are based upon sufficient data to accurately represent the flow system.

In referring to these tools, it is important to recognize the legislative and management differences between the jurisdictions where the tools were derived and the jurisdictions wishing to adopt them.

Numerical models are beneficial when assessing risks associated with particular land uses or potential contaminant sources that are located within the recharge area. Use of other delineation methods (*e.g.*, distance criteria or arbitrary fixed radius) could result in the protection of areas that are not actually contributing water to the well or conversely do not provide sufficient protection to high risk areas within an aquifer zone exhibiting high groundwater velocity towards the well.

Numerical models can serve as a predictive tool to help answer questions such as:

- How much water can safely be extracted from the aquifer over the long term? This can incorporate influences such as stream aquifer interaction and other demands on the aquifer including those from domestic wells.
- What are the effects of adding additional pumping wells or increasing the pumping rates?
- What separation distances are appropriate between the pumping wells to minimize the potential of well interference?

Data Collection and Measurement Tools

An excellent repository of data collection and measurement tools is available from the US EPA Office of Water (USEPA 1995). This listing includes references to useful data collection and measurement tools for microbial and other pollutants such as:

- Analytical Methods for the Determination of Pollutants in Wastewater Environmental Indicators
- Small Watershed Monitoring
- Volunteer Lake Monitoring: A Methods Manual
- Watershed Screening and Targeting Tool

Hydrologic Receiving Water/Watershed Modeling Tools

When properly calibrated, tested, and verified, hydrologic models are useful in the development of a watershed/aquifer protection plan because they can predict the long-term effects of watershed/aquifer management decisions on water quality. Watershed-scale models are specifically used to simulate and predict localized pollutant loading, transport, and transformation for microbial and other pollutants.

The goal of applying a loading model in a water quality investigation is to predict pollutant movement from the land surface to water bodies. Loading models range in complexity from simple loading rate assessments to complex simulation techniques that show the detailed processes of rainfall, runoff, sediment detachment, and transport to receiving waters. Some loading models work at the watershed/aquifer scale and sum all loads in the watershed/aquifer; others enable the watershed/aquifer to be subdivided into contributing sub-basins. Field-scale models are focused on a small, local scale.

Integrated modelling systems link the models, data, and user interface within a single system. Recent advances in modelling systems have supported geographical information systems and database management systems to conduct modelling and analysis. Geographical Information Systems (GIS) allow data preparation for watershed/aquifer and receiving water-modeling applications.

Hydrological tools use modelled simulations to predict hydrological impacts within a watershed/aquifer. Examples are listed in the sidebar.

The previously mentioned groundwater models can also be valuable tools in the development of wellhead protection plans as well as delineating wellhead protection areas.

Hydrological tools for watershed management include:

Hydrologic Simulation Program (HSPF) by US EPA: simulates sediment transport and movement of contaminants from agriculture/urban storm runoff. Continuous and single event model.

Soil and Water Assessment Tool (SWAT) by USDA ARS: predicts effects of land management on water sediment and chemical yields on large river basins. Continuous simulation.

Water Erosion Prediction Project (WEPP) by USDA ARS: predicts soil erosion and sedimentation. Continuous simulation, suitable for small watersheds.

Storm Water Management Model (SWMM) by US EPA: simulates urban runoff. Continuous and single event model.

Simulator for Water Resources in Rural Basins – Water Quality (SWRRBWQ) by USDA ARS: simulates hydrologic, sedimentation, and nutrient and pesticide transport in a large, rural watershed. Continuous simulation.

Agricultural Non-Point Source Pollution Model (AGNPS) by USDA ARS: examines water quality impact of agriculture and urban areas. Single storm event model.

GIS-aided Watershed Planning Tools

GIS-aided watershed/aquifer planning tools are extremely powerful and efficient tools for interpreting large quantities of data pertaining to a watershed/aquifer. Available GIS-aided tools include:

- Better Assessment Science Integrating Point and Non-Point Sources (BASINS) by US EPA: this tool offers integration of ArcView ver. 2.0 GIS software with U.S. watershed/aquifer data, and environmental assessment and modeling tools such as NPSM, TOXIROUTE and QUAL2E ver. 3.2.

- Watershed Decision Support System (WAMADSS) by CARES: integration of Arc/Info GIS with Agricultural Non-Point Source Model (AGNPS), Soil and Water Assessment Tool (SWAT), and Cost and Return Estimator (CARE) program.
- Watershed – The System by Linnet Geomatics Int.: a soil and water conservation system for local organizations.

Socio-economic Tools

Socio-economic tools offer analysis of anticipated social and economic impacts associated with considered watershed/aquifer management policies. Tools in the category include:

- Cost and Return Estimator (CARE) by USDA NRCS: generates costs and returns for crop enterprises.
- FLIPSIM by Texas A&M University: simulates the impacts of alternative farm and natural resource policies on the survival and profitability of representative farms.
- A Guide for Cost-Effectiveness and Cost Benefit Analysis of State and Local Water Protection Programs: the guide shows how to use cost-effectiveness and cost-benefit analysis to evaluate groundwater programs. The tools are presented in a step-by-step fashion so those unfamiliar with formal economics can still use them.

Decision Support Systems

Watershed planning and management can be complex. Making decisions that benefit stakeholders while maintaining watershed objectives can be challenging. The decision-making process is multidisciplinary in nature and must integrate variables such as scientific, socioeconomic and political knowledge. Fortunately, decision support systems (DSS) that make use of complex, dynamic knowledge from a number of disciplines, generally in a user-friendly graphical user interface, are available to decision makers. These systems allow users to organize information, design alternative watershed management plans and assess the consequences of these to stakeholders. It is recommended that people conducting long-term sustainable watershed planning and management consider the use of DSS.

6.2.5 *Implementing the plan*

Implementation of the plan consists of carrying through with the management actions recommended in the plan. Resources (human and monetary) will need to be mobilized and managed accordingly. An implementation schedule for conducting management activities will need to be developed and updated on a continuous basis. Effective schedules may include an order for addressing watersheds/aquifers that balances workloads from one year to the next; and a specified time limits for each assigned watershed/aquifer management action. The range and severity of each particular watershed/aquifer problem will dictate the time required in the implementation schedule.

Implementation instruments

Many instruments are available to stakeholders to help them implement the watershed/aquifer management plan. Some of these instruments take the form of legislation, government incentives, regulatory mechanisms and best management practices. These instruments generally focus on the management and/or prohibition of specific contaminants or land-uses within a given protection area.

Commonly used land-use and source control methods include both regulatory and non-regulatory controls. For examples of controls, see the box below.

REGULATORY AND NON-REGULATORY TOOLS FOR LAND-USE CONTROL

Regulatory tools

Zoning: Consists of dividing the municipality into districts and applying land use restrictions to the districts. Zoning generally restricts future development rather than existing land uses using mechanisms such as:

- prohibition of certain land uses and contaminants
- special permitting to regulate uses
- performance standards to regulate development
- reduction of undesirable land uses
- growth controls for the location and timing of development
- transfer of development rights to areas outside the protected areas.

Design and Operating Standards: Design standards usually control the standards for new engineering projects whereas operating standards control the operating standards for various engineering works and are generally administered through the use of by-laws, health regulations or performance standards. Standards for development projects other than drinking water treatment plants can include:

- siting criteria used to guide developments (*e.g.* residential)
- setback/buffer criteria to minimize detrimental impacts
- Storm water drainage diversion

Environment and Health Regulations: Enforcement of existing provincial and federal legislation developed for the protection of human health and the environment.

Non-regulatory tools

Land Acquisition: Used to control land use through purchase of one or more of the protected areas or the use of easements to limit development and land use practices

Land Use Planning and Designation of Protection Plans/Areas: May require inter-governmental agreements and cooperation. Examples include watershed plans and management and protection plans.

Voluntary and Municipal Contributions:

- public education to inform the community of the relationship between land use and drinking water quality;
- advisory committees to provide expertise and plan events
- hazardous waste collection
- water conservation programs
- stream clean ups
- Best Management Practices.

Capital Works Improvements: Improvements that could be completed with the protection area could include:

- installation or extension of treatment facility or municipal sewer
- removal or clean up of contaminant sources
- installation of spill prevention, containment and monitoring systems
- outright purchase of areas requiring protection.

Other non-regulatory avenues involve close supervision of water supply areas to identify and respond to contamination events or involvement of the public in protection initiatives. These measures are on the whole favourable and supplement nearly any source water protection program.

As part of their watershed/aquifer management strategy, municipalities may want to consider purchasing the land that makes up the watershed/aquifer from which they draw their drinking water. Rather than the entire watershed/aquifer, municipalities can also look at purchasing key parcels of land within the watershed, such as areas vulnerable to groundwater contamination or areas surrounding municipal wellheads. Some of the pros and cons of this approach are listed in the adjacent box. More often, partnerships will need to be established with other municipalities, organizations, landholders, and land users in many smaller municipalities. Often the area that needs protection will cross municipal boundaries. In that case, linking with other municipalities is a key component of watershed/aquifer management.

Purchasing a watershed

Pros:
1. High level of control over activities
2. Land can be identified as private property through signage
3. Violations can be dealt with as trespassing
4. Potential for forestry and rental revenues

Cons:
1. Purchase price can be high
2. Expense and liability of boundary maintenance
3. Occupier's liability
4. Patrol and enforcement costs
5. Property maintenance costs

Alternatives:
1. Controlling access points (rather than the entire area)
2. Establishing partnerships with other municipalities, organisations, stakeholders and land-users

(Yates 2001)

Other methods of controlling contamination, not yet commonly used in Canada, are based on the concept of total load allocations. Total load allocations establish the maximum amount of a pollutant a water body can receive, over a specific period of time, while continuing to meet federal and provincial water quality guidelines and objectives. The total load allocation policy for a water body should consider baseline levels of the pollutant prior to setting limits. An example of this instrument in a regulatory context is the Total Maximum Daily Loads (TMDLs) program used by the city of Winnipeg. TMDLs specify the maximum amount of a pollutant that a water body can receive and still meet the water quality standards, allocating pollutant loadings among point and non-point pollutant sources. The TMDL for a water body includes a safety factor to ensure that the carrying capacity for the contaminant is not exceeded by all point and non-point sources.

6.2.6 Performance Evaluation and Plan Readjustment

The on-going evaluation of watershed/aquifer management activities, progress and impacts is necessary to assess effectiveness of a watershed/aquifer protection plan. Review of monitoring data is critical in the evaluation of preventative and restorative source water efforts. This evaluation can be supplemented through consultation with watershed/aquifer stakeholder focus groups and the general public through open houses and questionnaires. Most of the evaluation effort can be managed by the Source Water Protection Committee.

The key to assessing the effectiveness of the watershed/aquifer management plan and its implementation is to compare source water monitoring data (see Section 7.1) to EQOs. This comparison is done to track progress towards achieving EQOs. Through this exercise, the Committee can refine the EQOs, review the management plan, and make adjustments as necessary.

7. Drinking Water Treatment and Distribution System Design

This section deals with the design of drinking water treatment plants and distribution systems based on the quality of the source water as determined in Section 6. This section starts with a discussion of regulatory requirements (7.1, 7.2 and 7.3) and then moves on to discuss how to design treatment and distribution systems in order to meet those requirements. On-going operational considerations are discussed in Section 8.

Remember that regulatory requirements vary across the country. Owners and operators are strongly encouraged to first understand and meet the regulatory requirements of their particular jurisdiction before considering the guidance laid out in this document.

The source water assessment outlined in Section 6 is followed by the selection of the appropriate technology to treat the source water. Water treatment process selection is a complex task involving many factors. The selection of the treatment processes is dictated by the need to produce acceptable water quality in a cost effective manner. The choice of water treatment depends on:

- Source water quality and quantity
- Finished water quality
- Reliability of process equipment
- Operational requirements and operator capabilities
- Flexibility in dealing with changing water quality
- Capital and operating costs

The impact of treatment processes on the environment also needs to be considered and minimized. Waterworks should be designed and approved by qualified professionals.

Water transmission and distribution mains are also a vital component of the waterworks system to ensure safe delivery of drinking water. To ensure water transmission and distribution mains do not adversely affect the quality of the water being conveyed, standards and guidelines have been established for pipe sizing, material, layout, and burial. Cross connection control and disinfection are also addressed. In establishing standards and guidelines for water transmission and distribution mains, the principal intent is to protect against contamination. In this regard, it is important for the standards and guidelines to be based on both on good engineering practices and on standards and guidelines that have either been set by other jurisdictions such as USEPA and WHO or set by standards/guidelines developing agencies/associations, *e.g.* CSA, AWWA and NSF.

Much of the guidance in this section has been adapted from Alberta Environment's Standards and Guidelines for Municipal Waterworks, Wastewater and Storm Drainage Systems (1997).

7.1 Facility Design, Performance and Monitoring

Adequate waterworks systems

Ensuring the adequacy of waterworks systems from a design and process standpoint is considered a major element of any public health protection and safe drinking water program. This may be achieved by:

i. Developing and publishing performance standards, design standards and design guidelines for municipal waterworks systems
ii. Undertaking project design reviews and issuance of approvals for the construction of the works based on compliance with standards and guidelines

Good operation of the waterworks system

The proper operation and maintenance of waterworks system is essential to ensure sustained production and delivery of good quality drinking water. This may be achieved by:

i. Issuing operating approvals for the waterworks system with system performance monitoring requirements
ii. Sponsoring/organizing operator training programs
iii. Certifying operators
iv. Inspecting facilities and reviewing plant optimization

In cases where certifying operators is not possible because an official program does not exist, or in cases where operators are certified but would like to add to their knowledge, operators are encouraged to take it upon themselves to find alternative training opportunities.

Comprehensive drinking water quality monitoring

As discussed in Section 8.12, it is important for provinces to establish reasonable and appropriate monitoring requirements for waterworks systems, which may include:

i. Operational monitoring conducted by the local authority to control/monitor the performance of water treatment processes
ii. Compliance monitoring conducted by the local authority to determine compliance with regulatory quality standards/guidelines
iii. Baseline or issue oriented monitoring conducted by the province and the local authority to develop/expand databases, to address a specific concern/problem, and to assess the need for, or implications of, a possible new drinking water quality guideline limit.

Appropriate abatement and enforcement

As discussed in Section 8.10, a comprehensive drinking water program includes both an abatement component (which involves working cooperatively with owners to prevent and/or solve drinking water supply or quality problems) as well as an enforcement component (which involves taking appropriate action when violations of specific requirements occur). Abatement and enforcement activities may involve:

i. Providing field assistance to operators and undertaking operational modifications to improve water quality
ii. Undertaking compliance monitoring reviews
iii. Investigating for non-compliance
iv. Undertaking enforcement action for non-compliance

Materials and chemical agents used in the provision of drinking water need to be appropriate for their intended use. In this respect, guidelines that have either been set by other jurisdictions such as USEPA and WHO or set by standards/guidelines developing agencies/associations (*e.g.* CSA, AWWA, ULC and NSF International) may be used. It is important for regulators to commit to requiring standards that are considered acceptable in cases where such standards are not already required.

7.2 Treatment requirements for systems on surface water or for systems on groundwater under the direct influence of surface water (GWUDI)

Water treatment systems relying on surface water or GWUDI[6] should filter the water following a number of accepted processes to reduce the turbidity, colour, organic load and the concentration of microbiological organisms (protozoa, bacteria, viruses, etc). In general, treatment facilities for a surface water source or groundwater source directly affected by surface water include screening, coagulation/flocculation, sedimentation, filtration, taste and odour control, and disinfection.

At minimum, treatment requirements for surface water systems or for systems on GWUDI is filtration and disinfection to ensure greater than:

- 99.9 per cent (3-log) reduction of *Cryptosporidium;*
- 99.9 per cent (3-log) reduction of *Giardia lamblia*; and
- 99.99 per cent (4-log) reduction of viruses,

at or before the first consumer. For systems with a distribution system, it is important for a residual of disinfectant to be maintained at all times.

Filtration of a surface water source or a groundwater source under the direct influence of surface waters may not be necessary if *all* the following conditions are met (adapted from the US EPA Surface Water Treatment Rule):

i. Disinfection reliably achieves at least a 99% (2-log) reduction of *Cryptosporidium* oocysts, a 99.9% (3-log) reduction of

[6] For information on determining whether groundwater is under the influence of surface water (GWUDI), see Section 6.1.1

Giardia lamblia cysts and a 99.99% (4-log) reduction of viruses. Overall inactivation must be met using a minimum of two disinfectants. More than a 99% (2-log) reduction of *Cryptosporidium* oocysts and more than a 99.9% (3-log) reduction of *Giardia lamblia* cysts must be achieved if source water cyst/oocyst levels are greater than 1/100 L. Background levels for *Giardia lamblia* cysts and *Cryptosporidium* oocysts in the source water must be established by monitoring every quarter or more frequently during the periods of expected highest levels (*e.g.*, during spring runoff or after heavy rainfall).

ii. Prior to the point where the disinfectant is applied, the source water *E.coli* concentration does not exceed 20/100 mL, or the total coliform concentration does not exceed 100/100 mL, in at least 90% of the weekly samples from the previous six months.

iii. Average daily source water turbidity levels measured at equal intervals (at least every four hours) immediately prior to where the disinfectant is applied do not exceed 5.0 NTU for more than two days in a 12-month period.

iv. A watershed/aquifer control program (*e.g.*, protected watershed/aquifer, controlled discharges, etc.) is maintained that minimizes the potential for faecal contamination in the source water.

7.3 Treatment Standards for Groundwater

In general, groundwater treatment plants are less complex than surface water treatment plants. The minimum treatment requirement for systems on groundwater is disinfection to ensure greater than 99.99 per cent (4-log) reduction of viruses, at or before the first consumer. Under certain circumstances, system specific exemptions for disinfection may be granted by some jurisdictions.

Dissolved minerals such as iron, manganese and, in some cases, dissolved metals can also be an issue. Therefore, in addition to disinfection, other treatment processes may be required. The type of treatment will depend on which substances are present and in what concentrations.

7.4 Surface Water Supply

7.4.1 Water Source / Quality

Source water from a selected source should be of sufficient quality that it can be economically treated to produce finished water that complies with the drinking water quality and treatment performance requirements. Factors that influence the choice of the source water should include reliability, treatability, environmental impact, and economics.

As the level of treatment required is dependent on the source water quality, the local authorities may develop watershed/aquifer protection programs to reduce any potential risk of source pollution. The local authorities may maintain a sanitary control area around all sources to protect them from existing and potential sources of contamination (see Section 8.9). As discussed in Section 6.2, the local authorities, in concert with other stakeholders, may also develop a watershed/aquifer control program, identifying land ownership and activities that may adversely affect source water quality. Watershed/aquifer control measures would then be developed, including documentation of ownership and relevant written agreements, and monitoring of activities and water quality (see Section 6.2).

7.4.2 Source Water Intake

Various components of waterworks systems should have a design life that is compatible with the function of the component. For example, a water treatment plant should be designed for a minimum period of 10 years with provision for expansion to handle a 20 or 25 year design flow. Intakes and outfall structures, which have high base construction costs, should be designed to be able to handle increases in water demand for longer than the design horizon, which is usually about 25 to 50 years.

Intake design should account for wave action and should provide adequate protection against the effects of ice and boat anchors. Intakes should be identified with buoys or reflectors where in proximity to shipping or recreational activities. It is important for the designer to be familiar with the requirements as legislated under the *Navigable Waters Act* and the *Fisheries Act*.

The inlet should be located to prevent bottom sediments from being picked up. For small intakes, consideration should be given to providing means for back-flushing the intake, if practical.

The design of river intakes differs from that for lakes and stagnant water bodies since more secure anchoring is required to resist bottom scouring and stream velocities. River intakes should be equipped with trash racks and should also be located well upstream from potential sources of pollution.

An acceptable alternative design to direct intake is an infiltration gallery intake. This type of intake is suitable when the river-bed is composed of gravels and rocks or if the floodplain is demonstrated to have a high water table that is connected to the nearby watercourse. Items to be considered are:

i. The sediment load in the river (may necessitate backwashing or aeration provisions)
ii. The use of filter cloth
iii. The depth of perforated infiltration pipes (to be located as deep as possible in the aquifer so as not to be affected by seasonal fluctuations)

7.4.3 Source Water Storage

Source water storage improves water quality by providing pre-sedimentation of solids, ensures an adequate supply when a stream or lake source is intermittent, and provides standby against failure of intake facilities. It also enables the operator to avoid the undesirable practice of drawing water during periods of poor source water quality, allowing a low rate of withdrawal at the source.

Facility Planning

It is important for the designer to assess the need, location, and sizing of the source water storage reservoir before proceeding with final design. Reservoir sizing should be determined by assessing the availability of water and the nature of upstream activities. It is also important for the designer to consider any potential adverse effects on the water intake, storage, or treatment facilities; design features should be used to minimize the effects of fluctuating source water turbidity.

Multi-Cell Provision

Source water reservoirs should be constructed with a minimum of two cells. This feature enables the plant operator to withdraw source water from the second cell when the first cell is being filled or repaired. For reservoirs that may be filled only once annually, each cell should be sized to retain about 75% of the annual source water needs. In areas of drought, the number of cells and the storage capacity of each should be increased to overcome long-term droughts.

Control structures should enable the plant operator to isolate each cell, to drain each cell, and to enable the cells to be operated in series or in parallel. A bypass around the reservoirs may also be provided to obtain water during those periods when reservoirs are out of service.

Each cell should be deep enough to restrict light penetration within the depth of the reservoir to mitigate the development of ideal habitats for aquatic plants.

It is important to armor the inside slopes of the cells, where required, to prevent erosion. It is also important to account for the impact of ice formation on winter storage in the design.

Reservoir Management

It is important for the local authorities to have a reservoir management program that identifies the current condition of the reservoir, the necessary storage capacity, and the necessary management procedures to respond to changes in reservoir conditions.

Reservoirs need to be managed to avoid any difficulties with taste, odour, colour, iron and manganese in drinking water. In-reservoir management techniques should address problems with algae, weeds, low dissolved oxygen, and loss of storage capacity.

Artificial circulation, aeration, phosphorus precipitation, sediment removal, dilution, and flushing are reservoir management techniques that improve water quality.

For more information on operational issues, see Section 8.

Lining

Source water reservoirs should be designed to minimize seepage. If necessary, the reservoirs should be lined.

7.4.4 Source Water Pumping

Pumps should be specified so the full range of anticipated flows can be provided with pumps operating close to optimum efficiency, with due regard paid to the hydraulic design of the discharge piping. This is often accomplished by selecting pumps that have wide band efficiencies and a relatively flat operating curve.

The number of pumps should be consistent with the pattern of flow required and the method of flow control. It is recommended that at least three pumps be provided for operating flexibility; a minimum of two pumps is required, one as standby. Pump capacities should be such that with the largest unit out of service, the remainder will be able to supply the treatment plant capacity.

The station design should allow for future additional pumping units and where possible, the pipework should be large enough for an increase in pump size to be accommodated. Adequate space should be provided for the installation of these additional units, and to allow safe servicing of all equipment.

Adequate space should be provided to remove the pumps. In the case of vertical turbine pumps, it may be necessary to provide a roof access for removing the units and sectional discharge pipes so that they can be completely removed from the source water well.

All piping should be arranged so there is sufficient room to service all valves and other parts, and to permit their removal with minimum disturbance to the system. A bridge crane, monorail, lifting hooks, hoist or other adequate facilities should be provided for servicing or removing equipment.

The pumps should be capable of supplying the water over the entire range of flows to be treated. This could be achieved through the provision of pumps with variable speed motors or through control valves. At small treatment plants where substantial seasonal variations in flow exist, it may be necessary to provide duplicate flow control systems - one suitable for very low flows (which normally occur in winter) and one suitable for the plant design flow.

7.5 Groundwater Supply

7.5.1 Siting of Wells

Wells should be located to avoid proximity to sources of pollution and/or flooding. Wells should be at least 100 m upgradient from pollution sources such as septic tanks, drainage fields, cesspools, or wastewater stabilization ponds; wells should not be located near sanitary landfill sites, underground fuel storage tanks, or cemeteries. Reasonable access should be provided for repair and maintenance.

7.5.2 Well Protection

In order to protect the finished supply structure from external contamination, the following should be provided:

i. Water-tight construction to at least 6 m below ground level. This depth may be increased if local conditions present a danger of surface contamination
ii. An annular opening of at least 40 mm outside the protective casing, filled with an approved grouting material
iii. Other precautions in the design to seal off undesirable subsurface formations and surface contamination

7.5.3 Pumphouse Design

The design criteria for well pumping stations generally follow those presented for raw surface water pumping, and standby-pumping facilities should be provided which are capable of maintaining normal servicing standards. Design should include features to prevent contamination of the well. In particular, return pipes that will permit water to be recirculated down the well should be avoided as they may cause contamination of the well.

7.5.4 Well Disinfection

Prior to using a water well, it should be disinfected in accordance with provincial/territorial requirements or to AWWA Standard C654-97. In general, chlorine should be applied to ensure that a concentration of 50 mg/L is present in the well for a period of twelve hours. Dosage should be calculated on the basis of the amount of water required to provide mixing throughout the entire well volume.

7.6 Treatment Processes

Treatment processes, particularly for municipal water supplies, generally include filtration and disinfection. Various filtration and disinfection technologies are discussed later on in this section.

Selection of a suitable water treatment process for a given utility is always a complex task. Conditions are likely to be different for each water utility; adoption of an appropriate water treatment process by a water utility is influenced by the necessity to meet the regulatory guidelines, the desire of the utility and its customers to meet other water quality objectives and the need to provide water service at the lowest reasonable cost.

A water treatment plant should be designed considering the fact that it should supply continuous and safe water to the customers regardless of the source water characteristics and the environmental conditions.

The source water quality is the single most important factor in determining the type and the extent of treatment required for a particular source of water. Thus, as discussed in Section 6, a thorough evaluation of the source water types should precede the selection of a treatment process.

The major source water characteristics are microbiological quality, turbidity, pH, alkalinity, colour, TOC, TSS, iron, manganese, algal counts, and temperature. Table 7.1 shows a choice of filtration processes, based on some key source water parameters.

Table 7.1 Generalized capability of filtration systems to accommodate source water quality conditions

Treatment	General Restrictions		
	Total Coliforms (#/100 mL)	Turbidity (NTU)	Colour (TCU)
Conventional with pre or in-plant disinfection*	< 20,000***	No restrictions	< 75
Conventional without pre or in-plant disinfection*	< 5,000	No restrictions	< 75
Direct filtration**	< 500	< 7-14	< 40
Slow sand filtration	< 800	< 10	< 5

* Must ensure control of disinfection by-products
** When TOC > 3 mg/L turbidity reduction is impaired
*** When total coliforms > 20,000/100 mL, or colour > 75 TCU, additional treatment may be required

Note: Ideally pilot testing should be conducted to demonstrate the efficacy of the treatment alternatives.

Preferably a five year history that characterizes the main source water types would be collected. While such data collection is possible for locations where a water treatment plant already exists, it could be impractical for new locations. Therefore, data that characterizes the main water types for at least one year should be collected as a minimum. Facilities located upstream and/or downstream from a proposed site may be able to provide valuable information on the source water characteristics.

Conventional treatment is often the treatment of choice in producing safe drinking water. Chemical mixing is often the first and also an important step in the process train. Mixing is critical for uniform dispersion of the coagulant with the source water in order to avoid over or under treatment of the water. An understanding of water chemistry and the process of coagulation-flocculation is extremely important in the design of the components of a rapid-mix unit. The water quality, mode of destabilization, and the type of coagulant all play a part in the selection and design of the appropriate unit.

Table 7.2 provides some basic information on the selection of treatment methods and primary coagulants for different source water quality. The designer is well advised to verify this by undertaking bench-scale or pilot tests.

Table 7.2 Treatment Methods

Water Quality	Primary Mode of Destabilization	Primary Coagulant	Flocculant Aid	Treatment Method	Recommended Rapid Mixer
High Inorganic Turbidity, High or Low Alkalinity	Enhanced Coagulation	Inorganic Salt	If required	Conventional	ILM
High TOC, High or Low Alkalinity	Charge Neutralization	Inorganic Salt	Yes	Conventional	ILM
Low Inorganic Turbidity, High or Low Alkalinity	Enhanced Coagulation	Inorganic Salt	Yes	Conventional	ILM, S, BM, PJ**
	Charge Neutralization	Polymer, inorganic salt	No	Direct Filtration	ILM, S*, PJ*, BM*
Low TOC, High or Low Alkalinity	Enhanced Coagulation	Inorganic Salt	Yes	Conventional	ILM, S, PJ**, BM
	Charge Neutralization	Polymer, Inorganic Salt	No	Direct Filtration	ILM, S*, PJ*, BM*

*S, PJ and BM may be used with polymers only; *PJ may be used for waters with low alkalinity
PJ=Pressured Water Jets; BM=Backmix Reactor ; ILM=In-line Mechanical Mixer; S=In-line Static Mixer

Typical Ranges

High Inorganic (Turbidity) > 100 NTU   High TOC (Colour) > 5 mg/L   High Alkalinity > 100 mg/L as $CaCO_3$
Low Inorganic (Turbidity) < 10 NTU   Low TOC (Colour) < 2 mg/L   Low Alkalinity < 30 mg/L as $CaCO_3$

Notes:

1. For enhanced coagulation, waters with low alkalinity should be buffered if inorganic salts that would lower the pH are used.
2. Charge neutralization by inorganic salt, compared to enhanced coagulation, would require lower dosage of the salt.
3. A combination of inorganic salts and polymers could be used for optimizing the process, and often provides the best results.
4. Chemicals used as flocculant aid should be added after the addition of primary coagulant, prior to or at the flocculation unit.
5. Colour is best removed in the pH range of 4 to 5.5 with inorganic salts (alum) by charge neutralization; this pH range may not be the optimum for turbidity removal.

7.6.1 Treatment Plant Chemicals and Waste - Handling and Disposal

It is important to provide for proper treatment and/or disposal of all water treatment plant chemicals and wastes, including sanitary wastes, filter backwash, filter-to-waste.

Water Treatment Chemicals

a. Labels and Materials Safety Data Sheets

Federal and most provincial jurisdictions require hazardous products stored at worksites to be labeled and information be made available to workers through Material Safety Data Sheets. Workers are required to be knowledgeable about the Workplace Hazardous Materials Information System (WHMIS).

Most chemicals used for water treatment are "controlled products.” For appropriate use of the chemical, water treatment operators should be aware of the chemical purity (concentration), shelf life, expiry data, maximum dosage and use restrictions. This information can usually be found on the supplier labels but may be added to the worksite label for ease in use.

More specific information on the hazardous ingredients, hazards, health and safety risks, safe handling instructions, emergency and first aid measures are contained on a Material Safety Data Sheet (MSDS). MSDS obtained from the supplier and not more than three years old must be available at the worksite for all "controlled products" unless it is laboratory product where the label may contain all the information required on a MSDS.

b. Storage and Handling

Chemical storage areas should be segregated from the main areas of the treatment plant, with separate storage areas provided for each chemical. Where chemicals in storage may react dangerously with other materials in storage, segregated storage should be provided. The storage and feed equipment areas should be arranged for convenience of operation and observation, and located to provide easy access for chemical deliveries.

In general, storage areas should be arranged to prevent any chemical spills. As much as possible, all chemical storage should be at or above the surrounding grade. Storage areas should have eye-wash and/or deluge shower facilities, adequate facilities for cleaning up chemical spills, space for cleaning and storage of the recommended protective equipment, and adequate warning signs to identify hazards.

Chemical ventilation systems should be arranged so that air is exhausted outside the building and also so that slight negative pressures are maintained where dry chemicals are in use, as a dust control measure. Ventilation systems should be designed specifically for corrosive service, and special measures should be taken to prevent build-up of static or other explosive conditions.

Sanitary Wastes

It is important for all sanitary wastes from water treatment plants to be handled by direct discharge to a sanitary sewer system or to an approved wastewater treatment facility. These sanitary wastes should be kept separate from other process wastes to avoid the need to treat all plant wastes in the same manner as the sanitary wastes.

Filter Backwash

Backwash waste may be discharged directly to a sanitary sewer system, if the sewers and the wastewater treatment plant can withstand the hydraulic surges.

Backwash waste may not be discharged directly to an open body of water. Exceptions may be made only if it can be demonstrated that there are no significant adverse effects on the receiving body of water. Based on the quantity and quality of backwash waste and the sensitivity of the receiving body of water, regulatory agency may request for an impact assessment study to ascertain the need for backwash waste treatment before discharging to the environment.

Discharge of filter backwash water into a raw water reservoir or to the head works should not be permitted unless it receives off-line treatment or is returned to a location upstream of the coagulant dosage point so all the processes of a conventional or direct filtration plant are employed. Off-line treatment may be acceptable depending on the treatment method used in treating the backwash water.

For more information on filter backwash, see the US EPA's "Filter Backwash Recycling Rule" (www. epa.gov/OGWDW/filterbackwash.html)

Filter-to-Waste

Filter-to-waste may be discharged directly to a sanitary sewer system, if the sewers and the wastewater treatment plant can withstand the hydraulic surges. Filter-to-waste may also be recycled to the pre-treatment works or to the source water reservoir.

Clarifier blow-down

Disposal of clarifier blow-down (alum sludge) is generally determined on a site-specific basis. The following are a number of alternative methods of handling and disposing of aluminum sludge from water treatment plants:

a. Direct discharge to a wastewater treatment plant or sanitary sewer. Consideration should be given to the potential beneficial and adverse effects on the wastewater treatment facility;
b. Lagooning. Lagoons can be used as permanent storage facilities, long-detention settling lagoons to provide freeze/thaw cycle with supernatant disposal, or drying beds using evaporation;
c. Mechanical thickening and dewatering. Once thickened and dewatered, sludge can be placed at a disposal site, usually a landfill site used exclusively for sludge;
d. Direct discharge to a stream. This option should be considered only where there is a negligible environmental impact and it has been demonstrated that the aesthetics and downstream water users will not be affected; and

e. Land disposal. Land disposal to a sanitary landfill site or agricultural land of dilute or thickened and dewatered sludge is potentially harmful and should be reviewed with the regulatory authority prior to implementation.

7.6.2 Filtration Technologies

The filtration and disinfection treatment technologies identified below are not intended to be a comprehensive or exclusive list. Local authorities may choose alternative treatment technologies (*i.e.*, technologies not listed) that may be effective in producing water to meet the health based limits. Once again, the designer may conduct a pilot study to determine whether new emerging technologies meet the requirements.

For information on operating and maintaining filters, see "Filter Maintenance and Operations Guidance Manual" (2002) AWWARF Report ISBN 1-58321-234-5

FILTRATION TECHNOLOGIES

Conventional Filtration
Conventional filtration includes chemical coagulation, rapid mixing, and flocculation, followed by floc removal via sedimentation (or flotation). The clarified water is then filtered. Common filter media designs include sand, mono-media, dual-media, and tri-media, combining sand, anthracite, and other media. Design criteria are influenced by site-specific conditions and thus the criteria for individual components of the treatment train may vary between systems. Conventional treatment has demonstrated removal efficiencies greater than 99% for viruses and 97 to 99.9% (rapid filtration with coagulation and sedimentation) for Giardia lamblia.

Direct Filtration
Direct filtration has several effective variations. In general, though, all direct filtration systems include a chemical coagulation step followed by rapid mixing, and all exclude the use of a other clarification step such as sedimentation prior to filtration. Following the chemical mix, water is filtered through dual- or mixed-media filters using gravity units.

Slow sand filtration
Slow sand filters are similar to single media rapid-rate filters in some respects, but there are crucial differences in the mechanisms employed. The schmutzdecke, or top-most, biologically active layer of filter, removes suspended organic materials and microorganisms by biodegradation and other processes,

rather than by relying solely on simple filter straining or physio-chemical sorption. Advantages of slow sand filtration include its low maintenance requirements (since it does not require backwashing and requires less frequent cleaning) and its efficiency (which does not depend on actions of the operator). However, slow sand filters do require time for the schmutzdecke to develop after each cleaning. During this "ripening period," however, filter performance steadily improves. The ripening period can last from six hours to two weeks, but typically requires less than two days. A two day filter-to-waste period is recommended for typical sand filters

Diatomaceous earth (DE) filtration

DE filtration, also known as pre-coat or diatomite filtration, can be used to directly treat source water supplies with low turbidity or chemically coagulated, more turbid water sources. DE filters consist of a pre-coat layer of DE, approximately 1/8-inch thick, supported by a septum or filter element. To properly maintain the DE pre-coat layer, and to maintain porosity, treatment is supplemented by a continuous-body feed of diatomite and recycled filtered water. Intermittent operation of DE filters is not advised unless the system recycles water through the filter during production down times. Maintaining the filter in this manner optimizes performance, extends the filtration cycle, and lowers filter maintenance requirements.

Manganese Greensand Filtration

Manganese greensand is commonly used to removal iron and manganese from groundwater supplies. In some cases, it has been used to remove arsenic. The greensand media is typically regenerated by a continuous feed of potassium permanganate and/or chlorine ahead of the filter. The membrane filtration process can be pressure or vacuum driven.

Membrane Filtration Processes

The four treatments listed below are membrane processes which make use of pressure-driven semi-permeable membrane filters. Membranes are manufactured in a variety of configurations, materials and pore size distributions. The selection of membrane treatment for a particular drinking water application is determined by a number of factors: source water quality characteristics, treated water quality requirements, membrane pore size, molecular weight cutoff (MWCO), membrane materials and system/treatment configuration. Pre-filtration and scale-inhibiting chemical addition may be used to protect membranes from plugging effects, fouling and/or scaling, and to reduce operational and maintenance costs.

Reverse osmosis (RO) treatment operates in a high-pressure mode, and is effective in removing salts from brackish water and seawater. Due to typical RO membrane pore sizes and size exclusion capability (in the metallic ion and aqueous salt range), RO is effective for removing cysts, bacteria and viruses; however, RO produces the most wasted water (between 25-50% of the feed). Disinfection is still recommended to ensure the safety of water.

Nanofiltration (NF) treatment operates in a medium pressure mode, and is effective in removing calcium and magnesium ions (hardness) and/or natural organics and disinfection byproducts. Due to typical NF membrane pore sizes and (1 nanometer range), NF is effective for removal of cysts, bacteria and viruses. Disinfection is still recommended to ensure the safety of water.

Ultrafiltration (UF) treatment, characterized by a wide band of MWCOs, pore sizes and size exclusion capability (0.01 micron, molecular/ macromolecular range), operates in a low pressure mode and is effective in removing specific dissolved organics (*e.g.*, humic substances, for control of disinfection by-products) and particulates. UF is also effective for absolute removal of Giardia cysts and partial removal of bacteria and viruses. When used in combination with disinfection, UF would control these microorganisms in water. Tests have also shown that filtrate turbidity may be kept consistently at or below 0.1 NTU.

Microfiltration (MF), as with ultrafiltration operates in a low pressure mode, and is effective in removal of particulates. Due to typical MF membrane pore sizes and size exclusion capability (0.1 to 0.2 micron, macromolecular/ microparticle range), it is effective for absolute removal of Giardia cysts and partial removal of bacteria and viruses. When used in combination with disinfection, MF would control these microorganisms in water. Tests have also determined that filtrate turbidity may be kept low, typically at or below 0.1 NTU.

Table 7.3 shows various filtration technologies and the degree to which they are able to remove microbiological pathogens. The effectiveness of these processes on pathogen removal depends on water characteristics and operational conditions.

Table 7.3 Unit Processes and Their Ability for Removal of Pathogenic Microorganisms

Process	**Microorganism Reduction (log)**	
	Giardia	**Viruses**
Direct filtration /In-line filtration	1.5 to 4.0	1.0 to 2.0
Conventional filtration	2.0 to 6.0	1.0 to 3.0
Slow sand filtration	>3.0	1.0 to 3.0
Membrane filtration	>6.0	>2.0

7.6.3 Disinfection Technologies

Disinfection is an integral part of water treatment because it inactivates pathogens that are not physically removed by filtration. The degree of inactivation required is dependent on CT. CT refers to the product of the residual disinfectant concentration in mg/L, "C," and the disinfectant contact time in minutes, "T." "T" is the effective disinfection contact time, which is actually "T_{10}" – time for 10% of the water to pass through the point where "C" is measured. There is a relationship between CT values and inactivation rates (or log inactivation) for a given disinfectant. Since the determination of log inactivation of a microbiological contaminant is more technically demanding than the calculation of CT, CT is used as a surrogate for log inactivation for a given disinfectant under specific water quality conditions (*e.g.*, temperature, pH).

DISINFECTION TECHNOLOGIES

Chlorine

Chlorine has several forms and is the most widely used disinfectant in public water supplies. Hypochlorites are available in solid (tablet or granule), liquid (solution pump-fed) or gaseous forms. The use of gaseous chlorination at small water supplies may not be among the best disinfection options due to the hazardous nature of the material. Use of gaseous chlorine places greater demand on the need for isolated plant space, trained and attentive operating staff and protection from any hazards.

Use of hypochlorite solutions also warrants some precautions. With time, the disinfectant strength of the solution decreases and toxic chlorate levels in solution can increase. Awareness regarding the potential for producing elevated levels of halogenated disinfection by-products (*e.g.*, trihalomethanes, inorganic byproducts, and others) is also essential.

Chloramines

Chloramines, while possessing certain advantages over other disinfectants (*e.g.*, long residual effects and low production of disinfection by-products), are not widely used due to high costs and the complexity in operation. Compared to free chlorine and ozone, chloramines possess less potency as a germicidal agent, and would therefore require longer CTs.

Chloramine disinfection requires careful monitoring of the ratio of added chlorine to ammonia. Failure to do so can result in odor and taste problems or biological instability of water in the distribution system. Excess ammonia (*i.e.*, low chlorine:ammonia) can promote growth of nitrifying bacteria, which convert ammonia to nitrites and nitrates. The dose of ammonia should be tempered by any natural ammonia occurring in the source water.

Chlorine Dioxide

Chlorine dioxide, although a powerful oxidant, may be more difficult to handle than other forms of chlorine. Chlorine dioxide requires trained staff to manage its use and is so reactive that it may not provide a residual disinfectant in the distribution system.

Chlorine dioxide may be used for either taste and odour control or as a pre-disinfectant. Total residual oxidants (including chlorine dioxide and chlorite, but excluding chlorate) may not exceed 0.30 mg/L during normal operation or 0.50 mg/L (including chlorine dioxide, chlorite and chlorate) during periods of extreme variations in the source water supply.

Chlorine dioxide provides good Giardia and virus protection but its use is limited by the restriction on the maximum residual of 0.5 mg/L ClO_2/chlorite/chlorate allowed in finished water.

Where chlorine dioxide is approved for use as an oxidant, the preferred method of generation is to entrain chlorine gas into a packed reaction chamber with a 25% aqueous solution of sodium chlorite ($NaClO_2$).

Dry sodium chlorite is explosive and can cause fires in feed equipment if leaking solutions or spills are allowed to dry out.

Ozone

Ozone is a powerful oxidant with a high disinfectant capacity. Ozone is very effective in inactivating cysts, bacteria and viruses. Inactivation of 4-log to 6-log reduction can be achieved within very short contact periods. Design of ozone as a primary treatment should be based on simple criteria including ozone contact concentrations, competing ozone demands, and a minimum contact time to meet the required cyst and viral inactivation requirements.

Ozonation technology requires careful monitoring for ozone leaks which pose a hazard. Use of ozonation may also increase biodegradable organics in water which may affect distributed water quality. Additional treatment, such as granulated activated carbon filtration, may be used as necessary to mitigate the problem. Also, where bromides are present in source water there is an increased potential for the formation of disinfection by-products (*i.e.*, brominated organics and bromate) which should be minimized. Secondary disinfection with chlorine or chloramines may help in this regard by balancing treatment needs with the need for also protecting distributed water quality.

UV Radiation

Ultraviolet (UV) radiation is an effective disinfectant in treating relatively clean source waters. UV is a useful disinfection technology option given its simplicity of installation, ease of operation and maintenance, and low costs relative to chemical disinfection.

UV radiation as a germicidal agent is effectively applied at a wavelength of 253.7 nanometers through the application of low or medium pressure mercury lamps. UV dose is expressed in units of millijoule per square centimeter (mJ/cm2), the product of the intensity (I) of the UV lamp (mW/cm2) and time (T) of exposure (sec). UV treatment of water is therefore comparable to the CT as described above for chemical disinfection, since UV dose is expressed in terms of the IT values. At a germicidal fluence of 40 mJ/cm2, UV has been effective in inactivating Giardia to achieve 3-log reduction, Cryptosporidium and Bacillus subtilis at 4.5-log reduction, and MS2 coliphage at about 2-log reduction.

Natural organics, iron, calcium hardness, suspended solids, and other factors can reduce UV transmission and cause lamp fouling, thus decreasing the effectiveness of disinfection. In addition to pre-treatment and automatic cleaning systems to remove dissolved and/or suspended materials, which foul the lamps and impede UV performance, a secondary disinfectant is necessary to provide residual protection in distribution systems. UV intensity sensor readings, flow through the reactors, and temperature and lamp status should be monitored continuously to determine the daily average and minimum UV dose per reactor. Remote alarms, automatic cleaning of UV components, and annual UV sensor maintenance are also important design components to prevent deposition or scaling and to minimize on-site operator attention.

A full-scale equipment validation is paramount. It is extremely important for all UV units to have undergone manufacturer performance testing to verify the unit's capability with respect to inactivation of the target organisms. The validation protocol should be in accordance with one of:

- German Association on Gas and Water protocol (DVGW Technical Standard W294, UV Systems for Disinfection in Drinking Water Supplies – Requirements and Testing)
- Austrian protocol (ONORM M 5873-1);
- NWRI/AWWA document titled Ultraviolet Disinfection: Guidelines for Drinking Water and Water Reuse
- Proposed USEPA UV Guidance Manual for Drinking Water.

The effectiveness of the various alternative disinfection technologies on various pathogens is shown in Table 7.4. The effectiveness may vary according to water temperature and the concentration of disinfectant.

Table 7.4 Effectiveness of Alternative Disinfectants on Different Pathogens

Disinfectant	Micro organism E-coli and Inactivation Ability			
	E. Coli	*Giardia*	*Cryptosporidium*	Viruses
Chlorine	Very effective	Effective	Not effective	Very effective
Ozone	Very effective	Very effective	Very effective	Very effective
Chloramines	Effective	Not effective	Not effective	Not effective
Chlorine dioxide	Very effective	Very effective	Effective	Very effective
Ultraviolet radiation	Very effective	Very effective	Very effective	Effective

7.7 Water Distribution System

7.7.1 Design and Layout

It is important for the water distribution system to be designed to sustain the minimum operating pressure at the maximum hourly flows. Distribution systems should also be designed to eliminate dead-end sections. In cases where dead-end mains are unavoidable, measures should be taken to prevent stagnation. Where pipe performance standards exist, all materials that are used in the construction of the transmission and distribution systems should meet or exceed provincial/territorial requirements or AWWA, NSF or CSA standards.

7.7.2 Secondary Disinfection

To minimize the effects of accidental contamination within the distribution system and to prevent the re-growth of microbiological contaminants, a disinfection residual is required throughout the distribution system. Chlorine or chloramines are common secondary disinfectants due to the ability of these agents to provide a long-lasting residual.

7.7.3 Fire Flows and Hydrants

The provision of fire protection is solely the decision of the local authority. Where hydrants are provided, the leads should be valved for easy maintenance. Where groundwater levels are above the hydrant drain port, the drains should be plugged and the barrels pumped dry for winter conditions.

For details regarding fire protection requirements in municipal waterworks system design, the designer should refer to provincial/territorial requirements or the most current Fire Underwriters Survey publication entitled *Water Supply for Public Fire Protection - A Guide to Recommended Practice*.

7.7.4 Frost protection

To prevent freezing and damage due to frost, it is important for pipes to have a minimum cover above the crown of the pipe. The depth of frost penetration for the location may be calculated using the coldest three years during the past 30 years, or, where this period of record is not available, the coldest year during the past 10 years with an appropriate safety factor.

7.7.5 Cross-connection Controls

In order to avoid a physical connection between a watermain and a sanitary or storm sewer, which may allow the passage of wastewater into the potable water supply, cross-connection controls are necessary. They will work to prevent contaminants from entering the water distribution system.

For information on backflow prevention devices, see Appendix G

7.7.6 Horizontal Separation of Watermains and Sewers

It is important to maintain a horizontal separation between a watermain and a storm or a sanitary sewer to avoid any contamination. Most jurisdictions maintain at least 2.5 meters. Unusual conditions including excessive rock, dewatering problems, or congestion with other utilities may prevent the normal required horizontal separation of 2.5 m. Under these condition(s), a lesser separation distance may be allowed, provided that the crown of the sewer pipe is at least 0.5 m below the watermain invert. Where extreme conditions prevent maintaining the required vertical and horizontal separation, the sewer may be constructed of pipe and joint materials which are equivalent to watermain standards.

7.7.7 Backflow Prevention and Control

Backflow preventers are to be installed at any location where a connection is made to a distribution system located outside the service boundary of the approved waterworks system. Backflow preventers need to be installed in accordance with the latest edition of the Cross Connection Control Manual, published by AWWA (Western Canada).

7.7.8 Pumping

In general, the requirements for treated water pumping station are similar to those outlined in for source water pumping.

The distribution system by pumping should be designed with at least two pumps. With one pump out of service, the remaining pumps should be able to deliver the maximum hourly design flow at the design operating pressure.

In order to supply water economically during low demand periods, at least one pump should be provided with a variable speed motor or an appropriately sized, small pump may be installed.

Standby power or an auxiliary gas powered pump should be provided to supply water during power outages or other emergencies. Fuel should be stored above ground and outside the water treatment plant building.

7.7.9 Potable Water Storage

The total water storage requirements for a given water supply system where the treatment plant is only capable of satisfying the maximum daily design flow may be calculated using the following empirical formula:

$$S = (A + B + C) + D$$

where S = Total storage requirement, m^3

A = Fire storage, m^3

B = Equalization storage (approximately 25% of projected maximum daily design flow), m^3

C = Emergency storage (minimum of 15% of projected average daily design flow), m^3

D = Disinfection contact time (T_{10}) storage to meet the CT requirements, m^3

The level of storage may be further reduced if the water treatment plant is capable of supplying more than the maximum daily design flow or if there is sufficient flow data to support a lower peaking factor than would be normally used for the given population range.

It is important for the designer to recognize that the given formula for calculating treated water storage requirements needs to be supplemented with the storage required for the operation of the water treatment facility, *i.e.* filter backwash and domestic use.

7.7.10 Disinfection of Mains and Reservoirs

It is extremely important for all new or repaired watermains to be disinfected. Disinfection may be done in accordance with the American Water Works Association (AWWA) Standard for Disinfecting Water Mains. New lines should be thoroughly flushed and chlorinated. In repairing breaks, care needs to be taken to exclude dirt and ditch water. The section should be thoroughly flushed and disinfected. Following disinfection of all new watermains, it is important to assess the bacteriological quality of the water and to demonstrate that it is of acceptable quality before putting the mains in service.

It is also important to disinfect and flush treated water storage reservoirs, in accordance with the AWWA Standard, before putting them into service.

8. Total Quality Management

This section deals with the on-going operation and maintenance of the drinking water system, from source to tap.

Remember that regulatory requirements vary across the country. Owners and operators are strongly encouraged to first understand and meet the regulatory requirements of their particular jurisdiction before considering the guidance laid out in this document.

Once the components of the drinking water system are in place, from source to tap, they must be managed and operated effectively and consistently in order to provide a reliable supply of clean and safe drinking water. Internal activities such as daily, weekly, and monthly systems checks, full-cost accounting, appropriate operator training, emergency response planning, and a corrective actions program are all part of routine operational procedures. It is also important to hire appropriately skilled individuals and ensure they receive training to keep up-to-date. For their part, staff need to be aware of the requirements related to their work and exercise due diligence when carrying out their duties.

The information in this section looks at ways drinking water system owners and operators can ensure they are managing and operating their drinking water systems from source to tap as effectively as possible. Verification procedures include monitoring, record-keeping, reporting, evaluation processes such as auditing, and reviews and corrections of deviations.

One tool for ensuring the multiple barriers in the drinking water system are functioning effectively is to follow the Hazard Analysis and Critical Control Points (HACCP) approach. HACCP was originally developed by NASA and the Pillsbury Company for ensuring the safety of food used by astronauts, and is now the universally-accepted strategy for ensuring food safety.

When applied to drinking water, HACCP is an operational tool that requires programs to analyse their systems from source to tap to identify critical points where contaminants could enter the drinking water supply. Barriers are then implemented to block or control these contaminants. The principles of the approach are outlined in the box below.

HAZARD ANALYSIS AND CRITICAL CONTROL POINTS (HACCP)

HACCP is based on seven principles and five preliminary steps. Before the HACCP principles can be put in place, five preliminary steps must be taken. The first step is to create a multi-disciplinary team to analyze the drinking water system from source to tap. The team will be responsible for identifying existing and potential hazards in the system and conducting the hazard analysis. The second step is to describe the water system including the source water, water treatment processes, water storage and distribution systems, and any special considerations that need to be taken into account in order to keep drinking water clean, safe and reliable. The third step is to identify the intended uses of the water and what information consumers may need, especially during times when the water may not be safe to drink (*e.g.* during a boil water advisory) or when certain people may need to take extra precautions (*e.g.* the elderly or immuno-compromised). The fourth step is to create a flow diagram which shows all the steps used in the operation of the drinking water system, starting from the point at which a utility's responsibility starts and ending where its direct responsibility ends. The fifth and final step is to verify that the flow diagram is accurate and covers all pertinent information.

Once these five steps have been carried out, the seven HACCP principles can be followed. These principles are:

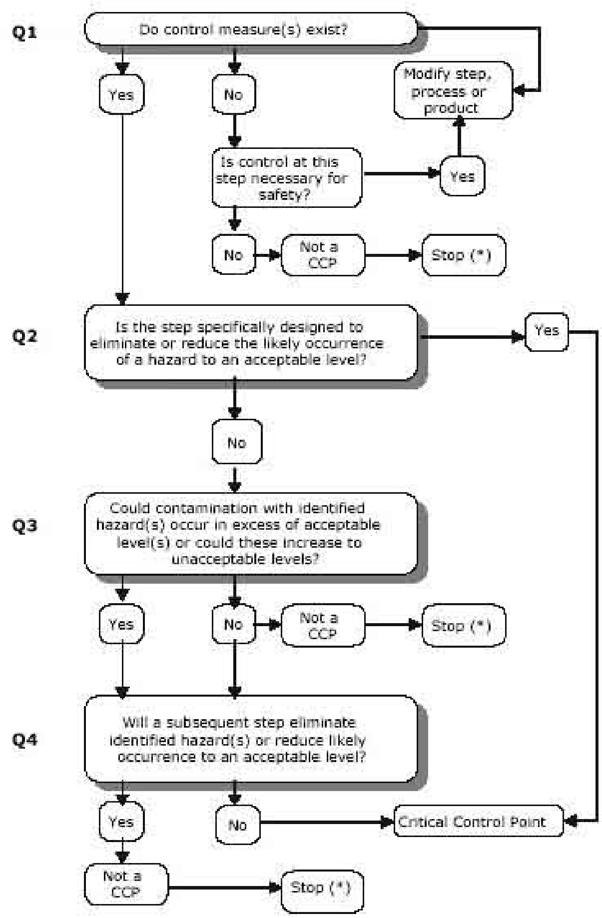
1. **Conducting a hazard analysis** to identify hazards that must be prevented, eliminated or reduced to produce safe drinking water.
2. **Determining Critical Control Points** (CCPs) to figure out where controls can be applied in the system to eliminate or reduce each hazard to an acceptable level.
3. **Establishing critical limit(s) for each CCP** to determine the absolute cut-off points to ensure water safety is maintained.
4. **Establishing a system to monitor each CCP** to make sure the critical limits are not exceeded.
5. **Establishing the corrective action to be taken when monitoring indicates a particular CCP is not under control.**
6. **Establishing procedures for verification to confirm that the HACCP system is working effectively.**
7. **Establishing documentation concerning all procedures and records appropriate**

to these principles and their application.

For more information on applying HACCP to drinking water systems, see the American Water Works Association's 2002 workshop manual, "The How, Where, and Why of Applying HACCP to Water."

Figure 8.1 shows the steps involved in determining Critical Control Points.

Figure 8.1 Flow Chart for Determining Critical Control Points



(*) Proceed to the next identified hazard in the described process

8.1 Monitoring, Record-keeping and Reporting

As discussed throughout this document, it is important for drinking water systems to be managed and operated in a holistic manner from source to tap, in order to ensure drinking water is kept clean, safe and reliable over the long term. It is important for watershed/aquifer management to follow the Watershed/Aquifer Management Plan as developed in Section 6 (and further discussed in Section 8). Drinking water treatment plants and distribution systems should be operated to meet the minimum performance expectations outlined in design manuals for treatment and distribution system components. Additionally, the treated water must, at a minimum, meet all drinking water quality standards as specified in applicable provincial or territorial regulations. Additionally, system operators should strive to meet or do better than national, provincial or territorial guidelines and objectives including the *Guidelines for Canadian Drinking Water Quality*.

In order to demonstrate the above and to assist owners and operators in managing and operating their drinking water systems, accurate records need to be kept. Tidy plans and record forms promote a sense of workmanship, operator pride, and make routine and emergency tasks easier.

Routine reporting, typically part of the operating approval, to regulatory agencies or preparedness for an audit is significantly easier with an accurate record keeping system. Additionally, ease of report/auditing helps assure a regulator that the owner and/or operator is capable of consistently producing safe drinking water.

8.1.1 Source Water Monitoring

Source water quality monitoring is an important component of the multi-barrier approach and drinking water quality management. Knowledge of source water quality and the assessed risks to public health help determine the need for source water protection efforts and the level of treatment required. Consistent and attentive monitoring practices provide valuable assessment data to staff. Monitoring provides key information for:

- Understanding and confirming threats and hazards
- Conducting assessments and determining the vulnerability of source waters
- Targeting source water protection and management strategies towards issues of concern
- Creating tools for promoting public awareness and community involvement (*e.g.* water quality indexes, status and trend reports)

Although monitoring can be costly and time consuming, its contribution to source water protection measures is invaluable. It is important for monitoring programs to be as comprehensive as possible. With specific water quality objectives in mind, all or some of the following elements should be included when considering monitoring approaches:

- Early warning or detection using a few core parameters as rapid detection indicators
- Systematic screening or periodic surveillance of targeted contaminants or activities (*e.g.* agricultural practices)
- Routine, long-term monitoring of characterized source waters and groundwater recharge zones

Once a monitoring program is in place, it is important to have an up-to-date inventory of known contaminants in the watershed/aquifer which have the potential to impact source waters. A contaminant inventory serves as a list of parameters that require periodic screening (see Appendix C). All source waters should be monitored for a baseline set of parameters, including bacteriological contamination, turbidity, natural organic matter and some chemical contaminants. The prevailing land-use and natural features of the watershed/aquifer should be kept in mind. It is important for water quality monitoring programs to be maintained over the long-term since contaminant levels respond to changes in land-use and watershed/aquifer management activities. Many provincial governments and local authorities have already implemented on-going water quality monitoring programs of surface water sources and should be consulted during this assessment. Monitoring of sub-watersheds (*e.g.* creeks, stormwater drains) and other protective activities may help determine the sources of contaminants. As a best practice, it is important to co-ordinate with other programs that collect monitoring data.

8.1.2 Treatment System and Compliance Monitoring

Reasonable monitoring requirements for water systems verify that treatment and operational processes are effective in providing safe drinking water. Monitoring is normally required for operational compliance established by regulatory agency and follow-up or incident purposes.

Compliance monitoring differs from operational or performance monitoring in that it is the minimum required by regulation or the operating authorization and is a legal requirement. Operational or performance monitoring goes beyond what is legally required and involves more in-depth and more frequent checks on the conditions that could affect the treatment, such as water alkalinity, pH, and temperature. It demonstrates how well the various stages of the multi-barrier system are working. Performance monitoring can serve as an early warning system whereby process changes can be implemented before treated water quality compliance is compromised.

Water system owners and operators are ultimately responsible for complying with the monitoring programs established within their jurisdiction. Compulsory monitoring requirements are included in drinking water programs because the ramifications to public health as the result of a failure within the water supply system are too great to rely solely on any one person or on monitoring results obtained after the water has reached the consumer. Each member of the drinking water program needs to actively participate by being aware of all the compliance monitoring requirements, ensuring that the requirements are being undertaken, and evaluating and responding to reported results.

If not already in place, it is important for the provincial or territorial government to establish compliance monitoring programs within their jurisdictions to provide checks on, and directions to, the water owner and/or operators. The government drinking water specialists might detect a situation that was not recognized by the water supplier and can provide emergency assistance when necessary. Public health officials and the officials responsible for the drinking water management program need to establish what monitoring is essential to ensure that the drinking water provided is safe. Although such a program needs to include monitoring the finished product for health protection, this monitoring is reactive and describes an existing health exposure. As discussed previously, rapid and (ideally) continuous process monitoring is essential to producing safe water.

Compliance monitoring normally includes in-plant daily monitoring of the disinfection process. In-plant compliance monitoring should also include monitoring of the treatment process against the established performance standards. It is important to focus attention on significant changes to water quality parameters. For example, where a source water has a significant risk of protozoan contamination and the treatment employed includes coagulation, flocculation, sedimentation, filtration, and disinfection, the monitoring requirement should include raw water turbidity, settled water turbidity, continuous turbidity monitoring of each filter, as well as, disinfectant contact (flow and concentration), pH, and temperature. Mandatory monitoring of these process conditions emphasizes the preventative priority of these processes, maintains a record of conditions that indicate adequate treatment, and establishes a routine that prevents a pathogen from passing through the plant.

Many provinces and territories have disinfectant monitoring programs which require samples to be taken at a minimum number of approved residual measurement locations. Compliance with a program is, however, a minimum required level of effort which owners and/or operators may need to exceed for their own operational purposes. It is advantageous for a owner and/or operator to continuously monitor disinfectant residual, particularly at the point where finished water is leaving the treatment plant.

A chlorine residual should be maintained in the distribution system at all times. To confirm that adequate residual disinfectant is present throughout the distribution system, measurements should be taken (and properly recorded) on a daily basis. Representative sampling locations include sites throughout the different pressure zones (if present), exit points from water storage, areas near to water main size changes, and at the far ends of the distribution system.

It is important for the operator to review the past routine measurements prior to his or her daily rounds in order to recognize a sudden change in, or absence of, the residual. Such a change should alert the operator to the possibility of a potential problem. He or she may need to take immediate action such as retaking the measurement, checking the equipment, and searching for the cause of contamination that is exerting the strong chlorine demand.

Disinfectant monitoring should also accompany routine tests, and any re-tests, for coliform bacteria. Sites returning sporadic residual measurements, low sporadic coliform values, and taste-odour complaints should be sampled for heterotrophic plate counts. This action should be coupled with an investigation of the surrounding building for cross-connections. Consistently low residuals, in spite of flushing and residual boosting, may indicate the age or condition of the water main materials.

It is important for owners and operators to meet the various compliance monitoring requirements set by regulators. Minimum monitoring standards reflect the needs associated with hazards posed by local conditions. Various methods may be used to ensure test results are accurate and reported properly. Compliance monitoring requirements typically deal with source water, in-plant treatment performance, finished water, and water within the distribution system.

8.1.3 Record Keeping

Records are needed for many reasons. In general, they promote the efficient operation of the water system. Records can remind the operator when routine operation or maintenance is necessary and help ensure that schedules will be maintained and required operation or maintenance will not be overlooked or forgotten. Records can be used to determine the financial health of the utility, provide the basic data on the system's property, operator training and employment files, and help in the preparation of monthly and annual reports.

Accurate and comprehensive records are key to an effective maintenance program. The onus rests on the water system owner to maintain extensive records as the regulatory agency normally acquires only a baseline amount of information. Typically, regulatory agencies only require owners to submit periodic water quality and operational records.

Another reason for keeping accurate and complete records of system operations relates to the utility's legal liability. Such records are required as evidence of what actually occurred in the system. Good records can help when threatened with litigation. Records also assist in answering consumer questions or complaints. It is very important for care to be taken where samples are recovered from private property to ensure a suitable degree of data privacy. In particular, it is important to keep personal data, including information that would identify the household, private. Finally, clear, concise records are required to effectively meet future planning needs.

Records may be tailored to meet the demands of the particular system; it is only necessary to keep records that are known to be useful. It is important for operators to determine what type of information will be of value for their system and then prepare maps, forms, or other types of records on which the needed information can be easily recorded and clearly shown. Records should be prepared as if they will be kept indefinitely.

It is good practice for all records to bear the signature of the operator in charge of the water system. It is important for system owners to keep these records available for inspection.

The following are examples of the types of records that should be kept:

- Source/system assessment
- Bacteriological and turbidity analysis results
- Chemical analysis results
- Records of daily source meter readings
- Other records of operation and analyses may be required by the regulators
- Laboratory reports including any summary tables
- Records of action taken by the system to correct events or violations of drinking water guidelines
- Copies of Engineer's reports, project reports, construction documents and related drawings, inspection reports and approvals
- Results of sanitary survey (if applicable)
- Where applicable, daily records including:
    - temperature at each residual concentration sampling point
    - pH if using chlorine
    - peak flow
    - filled capacity/depth of clear water tank
    - disinfectant contact time T, and corresponding concentration C
    - inactivation ratio
    - Residual disinfectant concentration entering the distribution system, and at representative points within the distribution system.
- Water treatment plant performance including but not limited to:
    - type of chemicals used and quantity
    - amount of water treated
    - results of analyses
    - turbidity
    - Control point meter readings

    - Other information as specified by the regulatory agency
- Additional information such as:
    - consumer complaints
    - water main flushing and cleaning
    - cross-connection control
    - unusual events (*e.g.*, extreme weather)

Common records identified above may be requested by regulators at any time.

8.1.4 Reporting

Regular reporting and feedback mechanisms are key operational and management practices. It is important for operations staff to be given the right tools to communicate information to management and, when appropriate, to the public.

The fact that most water system infrastructure is buried and "out of sight-out of mind," means many water system purveyors struggle for funds with more "visible" projects. Mayor and council should be regularly appraised of the operation of the water system and their responsibilities and liabilities and be forewarned of anticipated major capital improvements on the horizon.

The degree of reporting for drinking water systems required by the various regulatory agencies varies substantially across Canada. Generally speaking, traditional reporting falls into two principle categories:

- Routine water monitoring results to show operational conditions and/or compliance with requirements
- Upset or poor treatment performance conditions which (may) affect public health.

Upset or poor treatment system performance reporting is based on the fact that diligent operators are the first to discover minor or major system events.

A third consideration is the growing demand for more information to be made available to the public. System owners are encouraged to communicate actively with consumers and exceed the minimum reporting criteria of their province/territory.

Routine reporting of water quality results from analytical laboratories has also evolved over the past decade. There is an increasing onus on laboratories to simultaneously transmit sample test results to the owner and/or operator and the regulatory agency(s), the premise being that non-compliant results are more likely to be acted upon or forced to be acted upon.

In small- to medium- sized Canadian municipalities, communication between the mayor, council, administration and water system operators is fundamentally important for the consistent and safe provision of drinking water.

Internal communication is also of primary importance. It is important for water system owners and/or operators to ensure that open lines of communication exist among their staff as well as between operations staff and management. It is also extremely important for formal communication to exist between the management of a water system, regulators, and municipal councils. This formal communication should be supplemented by regular, informal means of communication. Frequent and factual communication between decision makers is paramount to the long term, efficient functioning of a water system. Operation staff have an obligation to inform decision makers, and decision-makers have a similar obligation to users to act upon the information with which they are provided. Any breakdown in reporting can be catastrophic to a community's health.

Funding allocations may also be dependant on good, frequent reporting. Prior to the budgeting process, it is important to have a realistic representation of the operating costs for the planning period, as well as an accurate inventory of assets. It is also important to forecast anticipated capital costs so appropriate funds can be allocated, borrowed, or reserved as needed. Frequent communication between operations staff, management and accounting personnel can help explain the requirements as well as providing decision-makers with details as to the consequences of not appropriating required funds. Without frequent communication between decision-makers who hold the financial control (and ultimate responsibility), the water utility can easily be neglected in terms of funding for operating and capital costs.

In complying with regulations set out by the appropriate regulatory agencies, operations personnel are required to complete and document a variety of inspections and tests. Although compliance tools vary from jurisdiction to jurisdiction, it is important for specific and precise guidelines for communicating discrepancies to be clearly and definitively outlined in advance. It is also important to follow appropriate auditing procedures to monitor that required procedures are being followed.

It is very important for monitoring results to be reported directly to the drinking water authority. These results may also need to be made available to the public, if requested. It is imperative that a reporting system be in place to inform the chain of command when test results show drinking water presents a potential health risk or to explain changes in aesthetic quality. It is particularly important to have protocols in place prior to embarking on any formal internal or external communication.

8.2 Laboratory Selection and Sampling Protocol

In order to ensure the accuracy of water quality data, it is important for drinking water utilities to have appropriate sampling protocols in place and to use accredited laboratories for compliance monitoring purposes. For other types of monitoring (*e.g.* monitoring done to ensure the treatment plant is optimized or performing as required), system owners/operators may use the laboratory of their choice.

> In Canada, the Standards Council of Canada (SCC) is the focal point for standardization and conformity assessment. The SCC, in cooperation with the Canadian Association for Environmental Analytical Laboratories (SCC/CAEAL), delivers a program for accrediting environmental testing laboratories (not necessarily drinking water laboratories). SCC/CAEAL define accreditation as “the formal recognition of the competence of a laboratory to carry out specific tests.” The SCC/CAEAL program accredits laboratories for individual parameter analyses.

The system owner and/or operator is responsible for collecting the appropriate samples at the correct locations, and for preserving and transporting the samples according to standard procedures. Once the samples are received at the laboratory, owners/operators no longer have control over the quality of the results. The correctness of the results is dependent on the quality of the analysis and data management procedures at the laboratory. The laboratory is, therefore, an essential participating partner in the drinking water program. Laboratory services are to be chosen carefully, considering the lab's commitment to quality. Laboratories with acceptable quality control and quality assurance programs usually have higher costs associated with maintaining these standards. It is important for laboratory users to understand the benefits associated with using quality laboratory services and commit to the higher costs associated with quality results, especially for legally-required compliance monitoring tests.

It is important for each jurisdiction to have approval processes in place for selecting laboratories or quality assurance programs. Laboratories need to use standardized methods, have quality control programs for their analytical work, and have quality assurance measures to ensure the data produced by the laboratory are valid. Laboratories should be accredited to perform the specific analyses required. Remember that laboratories are not always accredited to do all types of water analyses. For instance, it is extremely important that approved microbiological tests be those developed for drinking water; methodologies for environmental sample analysis are not appropriate in this situation.

Some university and private laboratories in Canada provide a proficiency testing service to drinking water laboratories. The laboratory should be accredited for the analysis specified. It is important for the responsible provincial and territorial governments to require all laboratory analysis conducted in response to compliance monitoring requirements be carried out by a laboratory accredited for that parameter and at concentrations present in drinking water. It is important for these governments to also maintain data tracking and auditing practices to identify situations where laboratory services and sampling practices compromise the data quality.

Each jurisdiction has its own sample collection and preservation protocols and/or specific criteria for sampling. In general, it is important for these protocols to be based on the latest edition of the “Standard Methods for the Examination of Water and Wastewater,” published by the American Public Health Association, American Water Works Association, and the Water Pollution Control Federation. One exception to this is microscopic particulate analysis (MPA) method which relies on a modified version of a USEPA consensus method.

8.3 TQM for Watersheds and Aquifers

System owners and operators have a clear role to play in implementing the watershed/aquifer management plan and on the source water protection committee (see Section 6). Owners and operators are encouraged to verify that the plan set out by the committee has been implemented, is managed effectively and that there is progress towards meeting the agreed upon environmental quality objectives (EQOs). The watershed/aquifer approach is a consensus-based approach among stakeholders that sets priorities and ultimately EQOs for the watershed/aquifer that focus on water quality for sources of drinking water. These objectives are performance criteria for source waters.

In many cases, system owners and operators will work closely with government agencies at the provincial, territorial and municipal level who have a lead role on the committee. The committee[7] will have terms of reference which includes a mandate and outlines roles and responsibilities of stakeholders, decision-making and conflict resolution processes, and other organizational/functional requirements. System owners and operators will have to work effectively within this multi-sectoral context to better influence decision-making at the watershed/aquifer level.

The watershed/aquifer management plan developed in Section 6 defined the problem and prioritized actions to meet EQOs. Certain sectors (*e.g.*, municipal waste water, agriculture, mining, forestry, pulp and paper) may be engaged more than others at reducing their contaminant load and may need to re-examine the TQM within their industry to assess whether they are meeting the discharge contaminant levels set out in their permits. Most have adopted or are developing TQM approaches within their industry that seek a balance between

Municipal wastewater TQM focuses on municipal wastewater treatment, residential on-site wastewater treatment, storm water management, biosolids, wastewater reuse, legislation, source control activities (industrial discharges) emerging issues, R&D and total quality service management. Professional and technical Associations of the operators enable this process to take place and devise Operational Plans, SOPs, and BMPs closely related to two international Standards series: ISO 9000 and ISO 14000.

[7] Because a committee structure varies depending on the water body size and location, the management structure will vary accordingly

environmental, social and financial interests. Municipal waste water is discussed in the adjacent box as an example of an industry with a discharge to source waters. Applying TQM approaches to diffuse or non-point source pollution such as agriculture is challenging as compared to a point source discharge. One option that can assist these managers with TQM is the development of standards for the industry. These provide goals and targets for the industry to optimize and improve on their TQM.

For case studies of water management approaches in Canada, see Appendix D.

For information on municipal governments and the protection of source waters, see Appendix E.

For more information on municipal wastewater treatment and its place in the multi-barrier approach, see Appendix F.

8.4 Treatment and Distribution System Operational Procedures

It is important for treatment plant and distribution system operators to follow established procedures for their facilities. They should also be given the opportunity to modify these procedures as necessary to ensure the water leaving the plant and moving through the distribution system is of the highest quality possible. At a minimum, it is very important for the facility to meet the minimum treatment performance requirements outlined in Section 7, as well as those mandated by the regulator.

When results of an inspection conducted by a regulatory agency or when operational data indicate conditions are, or may pose, a risk to public health, it is important for the owner and/or operator to take immediate corrective actions. Records should be made of the improvement activities.

As a precaution, it is also important for appropriate backup capabilities to be in place to protect against failures of the power supply, treatment process(es), equipment, or structure. Security measures should be adopted to protect the safety of the water source, water treatment processes, water storage facilities and the distribution system. The security measures used should be consistent with the probability of the occurrence of an unplanned event. In many jurisdictions, the regulatory agency must be notified of a significant system malfunction or upset. *More information about incident and emergency response planning is given in Section 8.7*

The following components are briefly reviewed to illustrate their importance: disinfectant monitoring, cross-connection control, watermain flushing program, valve and hydrant maintenance, line breaks and line commissioning, and leak detection.

For more information on optimizing water quality in the distribution system, see the AWWA document entitled, "Guidance Manual for Maintaining Distribution System Water Quality" and the AWWA manual M14, "Recommended Practice for Backflow Prevention and Cross-Connection Control."

8.4.1 Disinfectant Residual

On an operational level, maintaining and monitoring for a disinfectant residual in a distribution system is advantageous because:

- Routine residual detection provides a real time operation parameter
- The presence of a residual provides protection against bacteriological regrowth

Water entering a distribution system after treatment is of high quality. However, water quality can deteriorate since:

- The water is disinfected not sterilized
- Plumbing materials are not 100 per cent inert in water
- Intrusions (cross-connections, line breaks) to the piping occur
- Most water will precipitate some amount of compounds (calcium carbonate, iron, etc.) which provides a growth location for organisms

Bacteriological regrowth can lead to taste and odour complaints. Without a residual disinfectant, regrowth provides sites for enhanced corrosion of metal pipes. It should be noted that little evidence supports the concept that pathogenic organisms (should they be present) could become lodged in slime formed by organisms already established in the water mains.

8.4.2 Cross-Connection Control

The goal of a cross-connection control program is to stop the backflow of any source of pollution or contamination from entering the drinking water system. Backflow refers to any unwanted flow of water or substance from any domestic, industrial, or institutional piping system that enters into the potable water system. The direction of flow under these conditions is in the reverse direction from that normally intended.

Backflow may be caused by two specific conditions: a loss or reduction of pressure in the public water main causing flow outwards through a cross-connection (called backsiphonage), or excess pressure generated within a consumer's building which forces contaminants outwards through the cross-connection (called backpressure). In a back siphonage situation, the contaminant is siphoned back into the distribution system polluting some or all of the consumer's building system. It is also possible that the contaminated water could continue to backflow into the public distribution system. To prevent backflow from occurring at the point of a cross-connection, a backflow prevention device should be installed. However, it is important the backflow prevention device match the particular hydraulic conditions at that location and is suitable to protect against the degree of hazard present.

"Cross connection means any actual or potential connection between a potable water system and any source of pollution or contamination. Bypass arrangements, jumper connections, removable sections, swivel or change-over devices, or any other temporary or permanent connecting arrangements through which backflow may occur are considered to be cross connections."

Source: CAN/CSA-B64.10-01/B64.10.1-01, Manual for the Selection, Installation, Maintenance, and Field Testing of Backflow Prevention Devices -- Plumbing Products and Materials, A National Standard of Canada 2001.

Consumers can be protected in two ways from waterborne illness caused by backflow through cross-connections: by isolating the hazard at the point of connection or by providing the appropriate backflow prevention device on the service line as it enters the consumer's building. The second option is fundamentally important for the protection of the public water supply.

Waterworks systems can be protected from contamination due to cross-connection if they are designed and operated in accordance with the National Plumbing Code and CAN/CSA Standard B64.10.

For a description of the various types of backflow prevention devices, see Appendix G.

For more information, see:

- *"Manual for the selection, installation, maintenance, and field testing of backflow prevention devices-Plumbing products and materials: A National Standard of Canada 2001"*
- *"AWWA's Manual M14 Recommended Practice for Backflow Prevention and Cross-Connection Control and the University of Southern California Foundation for Cross-Connection Control and Hydraulic Research (USC-FCCHR) Manual of Cross Connection Control."*

As mentioned in Section 3, the key to establishing a cross-connection control program is awareness training of the appropriate utility personnel, municipal administrators, councillors, mayor, then public education and public relations. Most citizens, including elected officials, do not understand what a cross-connection is or the danger it represents to the public.

The municipality should lead by example and survey its own buildings to identify existing cross-connection hazards followed by (as a minimum) appropriate backflow device installation. Concurrent with the internal activities, the municipality has to decide how to establish authority (control) over the threats represented by cross-connections.

Once the program is underway, the municipality has an obligation to track devices, notify consumers of required testing, provide maintenance and inspection services, and enforce non-compliance as required.

8.4.3 Flushing Program

Flushing is done to clean out distribution pipelines by removing any impurities or sediment that may be present in the pipe, as these may result in taste, odour, and turbidity problems. Sand, rust, incrustations, and biological materials cause quality problems and are relatively common in pipelines.

Flushing should not be considered as the only solution to distribution system water quality problems. The water utility should always try to prevent water quality degradation through proper design, operation and treatment.

The frequency of routine flushing can usually be determined by consumer complaints and the types of material found during the flushing procedure, though water mains should be flushed before consumers start complaining about poor water quality. Flushing should be conducted during periods of low water demand (spring or fall), when the weather is suitable.

Prior planning and good communications allow the flushing crew to conduct the flushing operation quickly and without confusion. A significant part of prior planning requires that the owner and/or operator develop current water distribution system plans, illustrating locations of all valves, hydrants, and line sizes.

If flushing does not provide relief from water quality problems or from problems in maintaining the carrying capacity, mechanical cleaning devices are often used to clean pipes.

Recommended procedures for flushing and pipe cleaning are set out in Appendix H.

8.4.4 Valve and Hydrant Maintenance

Distribution system shutoff valves are provided primarily to isolate small areas for emergency maintenance. Operators should know exactly where to go to shut off any valves at any time in case of a line break or other emergency. A program of inspection, exercising and maintenance of valves on a regular basis can help water utilities avoid problems when the need to use a valve arises since most of these valves suffer from lack of operation rather than from wear.

An important factor in maintaining distribution system valves are the availability of current and correct maps of the distribution system. Each utility should verify their maps often so that they are accurate, and keep the map up to date by immediately recording any changes such as replacements or additions.

Operators responsible for hydrant inspections should be familiar with the various types of hydrants used in their distribution system. The supplier should be contacted whenever necessary to obtain descriptive literature, operation and maintenance instructions, parts manuals or assistance on particular problems.

In general, fire hydrants should be inspected and maintained as required. These operations are often done in the spring and the fall. However, each hydrant should also be inspected after each use.

Procedures for inspecting and maintaining valves and hydrants are given in Appendix I.

Additional information on valve and hydrant maintenance programs can be found in the manufacturers' product information, AWWA Standards C500, C502, C600, and AWWA Manuals M17 (Installation, Field Testing and Maintenance of Fire Hydrants) and M44 (Distribution Valves: Selection, Installation, Field Testing, and Maintenance)

8.4.5 Line Breaks and Commissioning

Breaks in water mains can occur at any time. It is extremely important for every owner and/or operator to have an established, written response plan. A break may be obvious, such as water spouting from a main as a result of a traffic accident, an earthquake or a washout. At other times, consumers may complain of a lack of pressure or no water at all and an underground break will have to be located. Ideally, before shutting off any valves, all affected consumers should be notified that they will be out of water for an estimated length of time. Advance notification allows consumers to make any necessary preparations for the period of time when water will not be available.

Prior to commissioning, lines should be disinfected, following the proper protocol as identified in the latest edition of AWWA C650 series standards.

Details on how to locate line breaks and remediate the situation are found in Appendix J.

For more information, see "Guidance Manual for Maintaining Distribution System Water Quality" (2002) AWWARF

8.4.6 Leak Detection

Even under the best conditions, all types of metal, concrete, and asbestos-cement pipe are subject to some deterioration. This deterioration may be revealed as a loss of water carrying capacity, leaks or degradation of water quality.

Leak detection programs are an effective means for some water utilities to reduce operating and maintenance costs. If a leak detection crew can reduce the flow of leaks and produce cost savings greater than the cost of maintaining the field crew, then the leak detection program is economically justified. Leak detection programs can also be justified in terms of early detection and repair of leaks while they are small, before serious failure occurs with resulting contamination, property damage, crew overtime, delays of other projects and similar problems. Also, a water shortage may require an effective leak detection program.

The total amount of leakage is also affected by the type of soil surrounding the pipes. In coarse soils (sands) the leakage may continue for an extended period without detection, whereas in finer soils (clays) leaks are detected sooner on the surface.

The process for detecting leaks is detailed in Appendix K.

For more information, see "Guidance Manual for Maintaining Distribution System Water Quality" (2002) AWWARF

8.5 Automated Systems

Automated sensors and alarms provide enhanced monitoring capability, in some systems process control, and notification of alarm situations. Where feasible, automated systems should be installed, operated and maintained per the manufacturer's recommended schedule. The degree of automation should be consistent with facility size, number of staff, and operator ability.

Prior to installing supervisory control and data acquisition (SCADA) equipment, the following conditions should be in place:

- A certified operator should be on standby status to respond to alarm notifications in a timely fashion.
- A certified operator should complete weekly system checks to ensure the accuracy of sensing equipment and to perform routine calibrations per the manufacturer's recommended schedule.
- The operations manual should include procedures for understanding automated control systems including upset conditions such as power interruptions.

Automated systems are well-suited to continuously monitor disinfection, which may be the principle treatment process for small water utilities.

For a list of recommended measurement instruments, alarms and status indicators, field instruments, and process controls, see Appendix L.

For more information, see "Water Treatment Plant Design 3rd Edition" AWWA and ASCE (pp576-604): McGraw Hill, 1998

8.6 Facility Classification and Operator Certification

Provinces and territories have their own certification programs for drinking water treatment and distribution system operators. Typically, these programs include two components: facility classification and operator certification.

8.6.1 Facility Classification

There are typically four classes of water and wastewater system categories. The classification of water treatment facilities is based on a range of points while the classification of water distribution systems is based upon the population served by the facilities. The purpose of classifying treatment and distribution systems is to identify and standardize the complexity of the facility such that appropriately certified people are assigned to its operation and maintenance.

Details on facility classification are given in Appendix M.

8.6.2 Operator Certification

Day-to-day operations of waterworks systems should be supervised by one or more persons who hold a valid certification for the type and class of facility concerned. This person(s) should be fully responsible for the operation and maintenance of the facility. Typically, the approval for each facility should state their required level of certification. The level of operator certification should match or exceed the classification of the water treatment/distribution facilities.

The required operator certification level for a particular treatment facility and distribution system is defined by the preceding classification system. Once a system is classified and the operators have been certified, it is normally the responsibility of certified operators to know and understand the terms and conditions in the regulatory agency's operating approval for their facility.

It is important that water system managers have a staffing plan(s) in place so that certified operator requirements are met during planned absences (*e.g.*, vacation), unplanned absences (*e.g.*, illness), or change of staff (*e.g.*, retirement).

In cases where no official certification program exists for drinking water treatment plant operators, operators are encouraged to take it upon themselves to find appropriate training opportunities.

A more complete description of staffing requirements, the education, and experience requirements for certified operators is found in Appendix N.

8.6.3 Continuing Education

Changing technology, regulatory requirements, and a general need to remain current, requires continuing education. As part of this education it is also recommended that open dialogue be maintained between operators, industry and regulators. There is a trend towards mandatory professional development which is common to many professions. Most Canadian provinces and territories currently rely on voluntary efforts by utilities and individuals to maintain their water works education requirements.

8.7 Tamper Policy

The purpose of a tamper policy is to establish who can work on and who has access to the drinking water system. The reasons for a policy are to ensure procedures when used and materials in contact with drinking water are properly disinfected, meet recognized quality of material standards and minimize the risk of cross contamination.

Access to the water system is generally for four main requirements: fire fighting, flushing, construction, and acquiring bulk water. For routine waterworks system operation and maintenance, the tamper policy should specify the degree of training and experience of personnel working on the waterworks system in addition to disinfection, materials and additive specifications.

In the case of bulk water hauling, the policy should be reinforced by penalty clauses in a by-law. Dedication of a relative few control fire hydrants or a similar bulk loading site should be viewed as a priority water quality security measure. The bulk filling station should be classified as a severe hazard and equipped with the appropriate backflow prevention device.

For more information see CSA Standard B64.10

8.8 Incident and Emergency Response Plans

There are two types of situations which can impact on the system owner's or operator's ability to provide safe drinking water to consumers. The first is an event in the source water which is generally out of the control of the owner and/or operator. The second is an operational interruption for which the owner or operator has direct responsibility. All owners and operators need to be aware of these situations and have an incident and emergency response plan in place to deal with events as they arise.

Incident and emergency response plans ensure the safety of the people who use the water from the drinking water system and are generally required in order to meet regulatory requirements. Responding rapidly and correctly to incidents and emergencies helps prevent unnecessary problems, protects consumers, and may save money by preventing further complications.

Properly prepared, well-thought out plans outline in specific detail the steps to take when an incident occurs, including who to call and what information they will need. In order to be effective, plans need to detail all the potential situations which could occur within the drinking water system in question and then outline specific solutions for each of those problems. The process of identifying potential problems may also serve to highlight ways in which emergencies can be avoided.

Common incidents could include line breaks, valve replacements, or extended electrical power outages. It is important that any work on the wells, standpipe, and distribution system follow proper disinfection protocol as identified in the latest edition of AWWA C650 series standards (C651-92, C652-92, C653-97, C654-87). Other possible incidents could include failure of a pump in one of the production wells; a highway accident involving fuel or chemical containers near the well field; one chlorinator failure; or failure of automated pump controls, switching, and/or recording instruments; the detection of *E. coli* in the water supply; large fires involving a business or more than one home; or a massive line break at the standpipe. Emergencies, particularly those involving the detection of *E. coli* in the water distribution system, require notification of the community using an up-to-date notification list which has the appropriate contact numbers.

TYPES OF EVENTS WHICH COULD IMPACT A DRINKING WATER SYSTEM

Experience in Canada indicates water system infrastructure is subject to a variety of event or threats. A number of these are described below.

Mechanical failures
Mechanical failures can include incidents such as pump breakdowns and valves jamming. Regular maintenance helps avoid problems before they begin, especially if employees are encouraged to be proactive about fixing and/or replacing aging equipment that is not yet broken but has a higher likelihood of breaking down. Back-up equipment should be on hand.

Environmental
Weather event extremes including floods, ice storms, hurricanes and forest fires should be assessed in terms of their impact on a water system. These events are normally short in duration and somewhat unpredictable and can affect source water quality, and the infrastructure which treats, stores and distributes the drinking water. Protective measures could include construction dykes or other barriers around the well and related treatment facilities.

Vandalism/Civil Disturbance
Sabotage can be subtle and difficult to predict. Protective measures

include review to detect where maximum damage can be accomplished with minimum effort, material, and danger for the saboteur and establishing barriers to prevent it.

Disgruntled Employee/Recently Released Employee

A troubled employee requires the consideration of their immediate manager and possibly others within the utility. The possibility of gross-negligence or disruptive action is problematic for a water owner and/or operator.

An employee who is to be transferred or released from the water utility should be required to:

- return all keys (metal and/or credit card style)
- Turn in any sensitive materials
- Return parking permits and associated passes/privileges provided as part of the water utility position

The utility needs to consider re-keying locks and changing electronic codes for doors. Web-based computer accounts and SCADA system access codes should be changed regularly and definitely when there is employee turnover. Passwords should be difficult to guess and the software should have virus protection.

Contamination

Regardless of the contaminant type, effective protective procedures or facilities could include:

- Monitoring, detection, and identification
- Alternative sources of water
- Alternative intake structures at varying reservoir depths
- System (on-line) storage in covered tanks
- Water purification facilities
- Developing an understanding of the type and character of the contaminant

One of the most likely sources of contamination is accidental spills of gasoline, oil, chemicals, or other hazardous materials.

The problem of contamination of reservoirs is best handled using closed or covered tanks, which make the intentional addition of contaminants more difficult. However, even the best protective measures need to be backed up by monitoring equipment and the capability to isolate contaminated storage from the water system.

Power Outages

The on-site generation of electricity requires fuel and the distribution of power requires transmission facilities. To prevent or reduce the effect of power disruption, utilities can: ensure the availability of standby generators, provide sufficient on-line reservoirs and gravity-flow lines to maintain limited distribution, make available portable generators. With on-site generation of electricity, the utility should have proper design and containment of any stored fuels, preferably outside of the immediate well house, treatment plant, etc.

Communication Disruption

Communication failures fall into two basic categories: failure of automatic signal equipment and associated telemetry, and failure of communications that link people. Protective measures for telemetry might include precoded operations at pumping stations, elevated reservoirs, intakes, treatment works, etc., which would put equipment on an automatic operating schedule in the event of signal failure.

Personnel contact can be best maintained by using a radio net that ties in control with remote stations, maintenance crews, and the homes of key employees. Use of cell phones greatly improves communication with employees working away from the office site.

Transportation failure
Transportation failure can be expected during adverse weather conditions . Protective measures include stockpiling basic materials, such as chemicals, chlorine, and critical spare parts.

8.8.1 Notification Lists

The purpose of developing and maintaining a current and complete notification list(s) including names, phone and fax numbers and e-mail addresses is to minimize the time and effort to notify municipal officials, at risk consumers, significant water users, and the regulatory agency(s). Depending on the type of incidents or emergency, all or some of these groups may require immediate notification.

In the event of a failure of a key component of the water treatment process (filter, chlorinator, etc.) or detection of *E. coli* at risk users such as (but not restricted to) seniors apartments-complexes, nursing homes, hospitals, daycares, and schools should be advised immediately. Significant water users could include food processing facilities and restaurants. The provincial/territorial water regulatory agency(s) typically have pre-determined criteria for mandatory notification. Regardless, the owner and/or operator should ensure current contact information, perhaps for multiple people to guarantee access. Media (TV, radio, newspaper) notification can be required in some water works situations such as advisement of a boil water order. The media can play an important role to provide occasional reminders to the public in situations where the boil order continues for an extended period of time.

8.8.2 Equipment Operations

Standard operating procedures for switching to alternative power supplies and/or maintaining generators (including schematics of electrical systems in pump houses) should also form part of the emergency response plan. These equipment procedures and plans should be kept next to the equipment to which they refer.

8.8.3 Incident Response: Boil Water Advisories

A boil water advisory is one example of a response to an incident or emergency. Advisories are usually only issued in cases of confirmed or suspected microbiological contamination. They are issued to protect public health while contamination of the water source is being confirmed and/or while the situation is being remediated.

Restrictions other than boiling the water may be required in the event of the presence of excessive inorganic, organic, or radiologic parameters concentrations, where boiling water is ineffective.

Regardless of the contaminants the owner and/or operator should have a process in place to determine the cause(s) of the concern, correct the problems, record the corrective action and to notify their consumers and regulatory agency(s). Part of the investigative efforts includes recovering water samples. Testing should be planned in order to obtain more information; it should not be viewed as a search for acceptable numbers in the absence of corrective actions.

Boil orders may be issued by the owner and/or operator, the community and/or the local Medical Officer of Health in situations where the water is causing, or may possibly cause, illness to the consuming public. Most provincial territorial regulatory agencies have a protocol in place for issuing and rescinding boil orders. Owners and/or operators should obtain and discuss the protocol with their regulators. Generally speaking, issuing and rescinding boil orders should be a well thought-out course of action, particularly in the absence of an assessment of the system, absence of waterborne illness in the community, or limited microbiological data (*i.e.,* little or no confirmed presence of *E. coli*).

During the boil order, consumers will either boil their drinking/food preparation water or seek an alternative safe supply. Particularly in the case of smaller communities, some people resort to using road side springs, shallow dug, or shallow drilled wells. These type of alternative supplies, without adequate disinfection and possibly additional treatment, are not considered a safe supply. Community assistance should be provided during boil orders to elderly people who live on their own. Generally speaking, it is preferable that the elderly not be boiling their own water due to an increased risk of scalding. This makes it necessary for someone else to carry in the heavy containers of bottled or other alternative supplies of drinking water.

As part of the water owner and/or operator's due diligence involving some water quality circumstances, issuance of a public statement to localized areas is warranted. The statement is intended for a situation that has a localized effect, such as an accident which breaks off a fire hydrant, a water main break, or the replacement of a portion of a water line. As part of being ready for situations before they arise, system owners may want to develop standardized procedures that are available for use at any time.

For more information on emergency planning, see "Emergency Planning for Water Utilities - Manual of Water Supply Practices M19" AWWA (2001)

For more information on boil water advisories, see "Guidance for Issuing and Rescinding Boil Water Advisories" (2001) Health Canada

8.9 Drinking Water Program Evaluations and Audits

8.9.1 Source Water Protection Plan Evaluations

On-going evaluation of watershed/aquifer management activities, progress and impacts is necessary to assess the effectiveness of a watershed/aquifer protection plan. This evaluation can be conducted through stakeholder focus groups and open houses and questionnaires aimed at the general public. Most of the evaluation effort can be managed by the Source Water Protection committee. Scientific data gathered through monitoring efforts is critical in evaluating preventative and restorative source water efforts.

8.9.2 System Vulnerability Assessment

A vulnerability assessment involves a critical review of all parts of a water system to document potential security weaknesses. This review should include all possible access points to every part of the water system from source to consumer service connection. Secondly, a list should be developed which identifies what can be improved or implemented to prevent access to that item. The assessment should include a review of existing policies and emergency preparedness plans.

The overall vulnerability analysis identifies the potential threats, the probability of the threat and consequence if the threat occurs. Prioritization of the threat by frequency of occurrence and magnitude of impact should assist in dedicating personnel and funds to minimize the issue.

For more information, see CWWA's CD-Rom publication "Vulnerability Assessment Template" (June 2003)

8.9.3 Audits

It is recommended that the type of audit described below be conducted every 3 to 5 years to ensure that the quality of the water and service provided by the water owner and/or operator is maintained. This time period is suggested since the time and effort needed to conduct a comprehensive audit may make it impractical for it to be conducted annually. Audits should look at the entire drinking water system, from source to tap.

Preparation for the Audit

The party chosen to conduct the audit should not only have a broad knowledge in water system operation, maintenance, treatment, monitoring, public health concepts and they should have a full grasp of the local regulatory requirements. They also should have skill sets which are pertinent to the water system which is to be audited. An audit can involve three phases, including planning, conducting, and compiling the final report.

Planning the Audit

Prior to conducting an audit, there should be a detailed review of the water system. The review should pay particular attention to past audits and documentation describing previously identified problems and the solutions. These should be noted, and action/inaction regarding these problems should be specifically verified in the field. Other information to review includes: any general documentation, water system plans, chemical and microbiological sampling results, operating reports, and engineering studies. This review will aid in the familiarization with the past history and present conditions, and the regulator's past interactions with the owner and/or operator.

The initial phase of the audit will comprise reviewing the owner and/or operator's monitoring records. Records should be reviewed for compliance with applicable microbiological, inorganic chemical, organic chemical, and radiological guidelines, and also for compliance with the appropriate monitoring requirements. The audit should provide an opportunity to review these records with the owner and/or operator, and to discuss solutions to any parameter non-compliance. The audit will also provide an opportunity to review how and where samples are collected, and how field measurements (turbidity, chlorine residual, fluoride, etc.) are made.

The pre-audit file review should generate a list of items to check in the field, and a list of questions about the system. It will also help to plan the format of the audit and to estimate how much time it may take. The next step is to make the initial contact with the system management to establish the survey date(s) and time. Any records, files, or people that will be referenced during the audit should be mentioned at the outset. Clearly laying out the intent of the audit up front will greatly help in managing the system, and will ensure that the audit goes smoothly without a need for repeat trips.

Conducting the Audit

The on-site portion of the audit is most important and will involve interviewing those in charge of managing the water system as well as operators and other technical people. The audit should also review all major system components from the treatment point to the distribution system. A standard form is frequently used to ensure that all major components and aspects of each system are consistently reviewed.

As the audit progresses, any deficiencies that are observed should be brought to the attention of the water system personnel, together with a discussion of suggested corrective measures. It is far better to clarify technical details and solutions while standing next to the problem. Points to cover include:

- Is the operator competent in performing the necessary field testing for operational control?
- Are any on-site testing facilities and equipment adequate, and do reagents used have an unexpired shelf life?
- Are field and other analytical instruments properly and regularly calibrated?
- Are records of field test results and water quality compliance monitoring results being maintained?
- Conduct any sampling which may be part of the survey.

Also, detailed notes of the findings and conversations should be taken so that the report of the audit will be an accurate reconstruction of the survey.

Audits can be conducted for the a variety of systems including treatment, filtration, distribution and administration.

Details on what to expect during the audit process, including the types of questions an auditor will ask, can be found in Appendix O.

Reporting the Audit

A final report of the audit should be completed as soon as possible to formally notify the owner and/or operator and/or the regulator of the findings. The report may be used for future compliance actions and inspections; it should include as a minimum:

- The date of the survey
- Who was present during the survey

- The findings of the survey
- The recommended improvements to identified problems
- Recommended dates for completion of any improvements.

The utility should be fully aware of the contents of the final report before receiving it.

More information on the various types of audits is given in Appendix O.

For more information on audits in general, see the USEPA Handbook: "Optimizing Water Treatment Plant Performance using the composite correction program"

8.10 Abatement and Enforcement

Abatement and enforcement should be considered totally separate functions handled by different staff working in the regulatory agency. The separation of enforcement activities from abatement activities means that abatement staff can focus on co-operative problem solving and prevention while maintaining a necessary image of advisors or resource people. Enforcement staff, on the other hand, should have no link or involvement with facilities on a routine basis so they can deal with enforcement issues in a more detached and impartial manner.

Abatement activities related to municipal waterworks systems may include:

- Regular inspections of a plant to examine the general operation and maintenance of the facility
- Follow-up letters and meetings with facility operators regarding any operational performance or reporting problems identified in the monthly/annual reports
- Assistance where operational modifications could result in significant drinking water quality improvements

Response to significant drinking water quality problems that require immediate resolution.

Since the continuous proper operation of a waterworks system is an essential aspect of providing safe drinking water, it is important to build a strong and co-operative link between the regulatory agency and municipalities with respect to facility operation and maintenance. The above abatement activities forge such a link. For example, the inspection activities ensure regular and direct contact between the regulator and the municipality and result in the establishment of specific operational-related contacts. To be effective, this contact should be seen as beneficial by the municipality.

The link with facility operators is further strengthened by the provision of direct in-field assistance on an as-requested or as-needed basis or when a significant problem or emergency arises. Assessments and evaluations of different water treatment chemicals and dosages, tracer studies to determine plant hydraulics, advice on chemical feed equipment and monitoring devices, general system operational reviews, and advice on maintenance requirements or needs are examples of specific abatement activities that can be undertaken by the regulatory agency.

Through a strong abatement program, many operational and performance problems can be prevented, or at least minimized, to optimize the performance of waterworks systems. This optimization results in the best possible quality of drinking water being produced by a facility on a continuous basis. Therefore, **operational- and maintenance-related abatement activities are a necessary component of any safe drinking water program**.

Enforcement activities should also be an integral part of the drinking water program. If an inspection of a facility or an investigation of an incident reveals a contravention of the legislation, the regulatory agency may use enforcement measures, including:

- Warning letters
- Tickets
- Administration penalties
- Enforcement orders
- Prosecutions

The intention of enforcement is to ensure appropriate remedial action and monitoring requirements are implemented to protect the quality of drinking water.

9. Public Awareness and Involvement

Public awareness and involvement in the drinking water program is extremely important for achieving the program's goals and objectives and should not be underestimated. Effective public involvement ensures stakeholders recognize and understand the drinking water program's policies and activities. It also enhances the legitimacy of decisions made and ensures the program's goals reflect public concerns, values and priorities (SERM 1995).

Public participation is important because it:

- Builds networks among key individuals in a community
- Identifies community needs and priorities with respect to drinking water quantity and quality
- Provides education and information to all residents of a community
- Focuses public attention on issues of concern
- Sets up a framework for community support of protective action
- Builds momentum for the program
- Provides the benefit of input and experience from a broad cross-section of the community

Public involvement initiatives can be incorporated into all aspects of the program, including:

- Source water protection planning
- The development of new, or expansion of existing, drinking water sources, including reservoirs
- The planning and development of infrastructure projects, especially those that require the approval of elected officials
- The development of new legislation, guidelines, programs and/or policies

In addition, the public should be kept informed of:

- Major repairs and maintenance of infrastructure, especially if disruptions to service will occur
- Water quality testing results that may affect their health
- Boil water advisories
- Measures that governments and/or utilities take to improve service
- Areas that need to be improved in order to ensure public health is safeguarded
- How water is being treated and why, and how water rates are set
- Where they can go for more information or to register a concern

Protecting the quality of drinking water begins with the public. The people who live in the source water area of a watershed/aquifer have a very important role to play. The kinds of things they do on a daily basis, as well as the pressures they exert on the governing bodies, have a direct effect on the quality of drinking water. The more people understand their role in both protecting and impacting water quality, and the more they participate in taking action to safeguard water quality, the better the management of the water resource, and the better the health of people in the community. Without a comprehensive, well-planned effort to include the public in development and implementation of drinking water programs, it is unlikely these programs will be successful.

Mismanaged public relations causes unnecessary reactionary management, and also forces managers to spend an inordinate amount of time correcting public perception, rather than managing their water system.

Public opinion has become a necessary consideration for managers of water systems. As drinking water consumers, the public is demanding greater access, timely reporting, and detailed information regarding almost all aspects of municipal water systems. In response to this, it is important for management personnel to create, in advance, a detailed communications plan as part of their overall operations plan.

A key to successful public relations is training in customer service and media relations. Many public relations hurdles can be overcome merely by answering questions promptly, factually, and courteously. Public utilities have an obligation to be transparent in their reporting. Any attempt to be otherwise will not only result in public relations problems, but may very well result in regulatory and legal infractions as well.

Communities may find that public information sessions and consultation forums provide excellent opportunities for communicating the benefits, as well as the constraints, of a water system to residents and industrial users alike. Prior to requesting a council allocate funds for capital infrastructure, input from a public information session may provide the necessary public support for appropriation.

Public information sessions are also a valuable part of the process for developing new guidelines and regulations. Community buy-in and participation prior to regulations taking effect show that questions and concerns were addressed as part of the decision-making process.

Drinking water programs can involve the public and increase awareness of drinking water quality issues by:

- Informing the public about its impact on source water quality and about available pollution mitigation measures.
- Informing the public about health risks and by providing educational materials on issues such as water disinfection, guidelines, conservation issues, and costs of providing service.
- Making monitoring results or summaries available and relaying information about what the authority is doing to address the risks.
- Issuing regular reports about drinking water systems, including improvements and areas that need further attention.
- Incorporating public consultations into decision-making processes that have an effect on public health, such as the development of new guidelines and regulations.

It is generally accepted that pro-active community communication, on a regular basis, can assist in the long term accomplishment of a water system's goals. Through on-going, pro-active communications, a community better understands the system. In being better informed, the community is also better prepared to accept future capital costs to improve, expand, and eventually replace the current system.

9.1 Components of Successful Public Awareness and Involvement

Public participation is the process by which all interest groups (stakeholders and the general public) in a community are provided the opportunity to make their views known on drinking water issues and protection, and to contribute to designing initiatives to improve water quality and quantity. It is important to make an effort to include the full range of community opinion in the discussion of possible approaches (adapted from US EPA 2002d).

Provinces may have a legislated public consultation process for informing and discussing important initiatives with the public. For example, in Ontario, the Environmental Bill of Rights establishes a formal framework for notifying the public about proposed legislation, policies, regulations and other legal instruments that could have a significant effect on the environment and then considering the public's input before the government makes a final decision. In addition, mandatory public consultation is required of a proponent of a proposed municipal water undertaking under the Environmental Assessment Act.

Public participation has many components, all of which should be considered. These components may include direct involvement of stakeholders in planning committees, involvement in general public informational meetings through submission of written and oral comments, and participation in community events such as art contests and demonstration projects. Additional components include development and distribution of educational products that target the public at large, such as fact sheets, posters, radio ads, brochures, and artwork.

Education and Community Awareness

Educational activities are those that use information and instruction to encourage awareness, understanding, and more informed decision-making. These types of activities tend to be one-way, in that the drinking water program will provide information to the public through resource materials, seminars, workshops and speakers.

Municipalities have opportunities to provide information and education campaigns to wide cross-section of their communities. The concept of the watershed/aquifer is an excellent model for making connections, since everybody lives in a watershed. This fact can form the basis of messages about how everyone has an impact on the watershed/aquifer and the health of a water source.

The watershed/aquifer management concept is also a useful way to encourage to take ownership of issues and make a positive impact on the environment. For example, householders make choices about the products they purchase and the methods of disposal. Linking what goes down the sink to what the downstream neighbor drinks is a helpful model to increase awareness and change behaviors.

Likewise, the concept of pollution prevention or cleaner production is particularly helpful in source water management, and may help reduce the level of disinfection need to ensure safe drinking water. This is part of the old fashioned concept that it is better to prevent a problem than to clean up afterwards. This can be part of community education messages, as well as active programs undertaken by municipalities.

Excellent community education programs have been developed for both general use and targeted groups such as schools. It is highly recommended that municipalities examine these existing programs and check if they can be adapted and adopted. In some cases, municipalities may be able to use existing brochures or poster artwork at considerable savings.

Working with the community and industry through education, and partnerships with stakeholders, including private landholders, and stakeholder groups, can be very powerful in changing behaviour over the long term and protecting source water. For instance, the call for a by-law could come from members of an industry or association that is concerned that some members are not undertaking best management practices and have an unfair advantage by being poor corporate citizens. In these cases, a by-law can be a useful tool for leveling the playing field and ensuring all industry players get treated equally. If a municipality does decide to establish a by-law, then it must be prepared to provide the resources and the time to enforce it.

Public consultations

Consultations are a form of structured dialogue between the government or utility and the public or other stakeholders. The goal of consultations is to receive input and achieve a common understanding of an issue or policy in order to develop acceptable solutions (SERM 1995). It is imperative when running a consultation process to be open to receiving and considering opinions that are different than the status quo or a pre-determined outcome. There is little point holding consultations if a desired outcome has already been selected, since building trust in the process is key to the success of future consultations. That said, the government or utility running the consultation process owns the right to make final decisions. Participants need to be made aware that while the organisation is committed to listening to all opinions, it will make the final decision based on its criteria. These criteria should be set out clearly prior to the start of the process.

Consultations can be done in person through steering committees, advisory groups, and task groups, or more informally through the solicitation of comments or feedback on documents provided to interested parties. It should be noted that while making materials available to stakeholders on-line (*i.e.* by posting documents on a website), some stakeholders do not have access to email and the Internet. Some effort will need to be made to ensure these people know about the consultation process and have a means to access and respond to any required documents.

Public meetings

A general public meeting can be a very effective way to introduce the issues relating to local drinking water issues, such as existing and potential problems with contamination of source waters and the impacts that contamination may be having on public health and the need for enhanced treatment. Public participation via meetings is the primary mechanism to involve all stakeholders and members of the public. It is critical to clearly invite public and stakeholder comment, emphasize the openness of the process, and assure that all public and stakeholder input will be given careful consideration.

Effective ways to publicize meetings and to solicit input on plan components are newspaper and radio announcements, posters, fliers, and word of mouth. Access to the public participation process is an important element to include when planning for public input. The lead person or agency needs to consider how it will reach people and organizations in remote areas of the community, as well as people with mobility, hearing, or literacy challenges.

Working with neighbouring communities

Coordination within a community, and between communities, can greatly increase the success of initiatives on source water protection. The boundaries and extent of water resources, such as a river or ground water aquifer, usually do not coincide with the borders of a single community or town. Therefore, for example, the effectiveness of actions taken in one community to protect its water source may be somewhat limited if similar actions are not taken by other communities sharing a given water source. Developing drinking water management plans that are compatible with, and supportive of, the plans of other communities sharing the same water source increases the overall effectiveness of individual community initiatives.

Working with the media

Involving the media during the development of initiatives can assist the process in a variety of ways. In addition to helping inform stakeholders and the public and increasing public involvement, the media can play a role in encouraging community support and communicating the value of source water protection and operation and maintenance programs. Visibility in the media can also communicate the need for financial and technical assistance to government bodies, national and international NGOs, and lending institutions. Figure 9.1 shows a sample media release.

Figure 9.1 Sample Media Release

Contact: [Name]
Phone: (123) 456-7890

FOR IMMEDIATE RELEASE
[Date]

Protect Your Drinking Water… Protect the Source!

[*City*], [Province]—Have you ever thought about where your drinking water comes from, beyond the faucet? Did you know that what you do in and around your home can affect not only the quality of your water but also the quality of your neighbor's water? Find out where your drinking water really comes from and learn about how you can help protect it during a [*Duration of campaign*]-month-long drinking water source awareness campaign, starting [*Start date*], sponsored by [*Name of sponsor*]. The campaign will provide information on

- The source of your local drinking water
- The value of safe drinking water
- Potential threats to your local drinking water
- Steps you can take to protect your drinking water
- Contact information for additional resources on drinking water protection.

Safe drinking water is essential to a community's quality of life and continued economic growth. Yet citizens may not always be aware of safe drinking water issues in their community and may not realize what needs to be done to protect drinking water and keep it safe for their families and businesses. Drinking water wells across the country are being contaminated daily by common activities, such as pouring motor oil and household chemicals down drains, using too much pesticides and fertilizers, and littering streets with refuse that will eventually run off into rivers and streams. When water supplies are not safe, the health of the community — especially of the young, the old, and the sick — is jeopardized. In addition, communities may experience a loss of tax revenues from real estate and new jobs as businesses refuse to locate to or remain in communities with known or suspected water contamination problems.

[Contact name and phone number]. [Acknowledgment]

Education of private land-owners

Private land-owners who draw their drinking water from sources on their own property are generally responsible for ensuring its quality. This responsibility includes having the water tested and implementing any remedial actions necessary to improve quality should it become degraded.

Where privately owned septic tanks may impact on public water sources, municipalities may be wise to ensuring these are being installed and managed appropriately. Remedial actions can be costly for the municipality in terms of staff time, and expensive for community members to comply with. It is, however, an area where cumulative impacts can cause major degradation problems.

As a minimum, municipalities can ensure their staff are well trained and able to evaluate septic system applications and their impacts. In locations where municipalities are not responsible for septic systems they should work with the authority to ensure that the safety of drinking water is protected. Likewise, owners of septic systems should be made aware of their responsibilities to properly locate and maintain their systems (AMO/MEA/OGRA, 2001).

Abandoned wells are another concern which can impact both private and public water supplies. While some provinces have established programs that require wellhead protection, municipalities do not have to wait to protect their groundwater resources.

Programs to identify and seal abandoned wells can be immediately instigated by the local authority. Abandoned wells provide an easy route of contamination into groundwater. This is particularly important when groundwater is the source of drinking water.

Municipalities can work with the public to highlight the relationships between wells and groundwater quality, and encourage community members to identify wells that can be sealed. While formal well protection programs may require the engagement of a hydro-geologist, considerable advanced work could be undertaken through engaging the community. If formal records are not accurate, requesting community input to identify old and abandoned wells can be a way of making connections for groundwater and surface water protection.

Appendix A: Municipal Drinking Water Policy

Example of a Municipal Drinking Water Quality Policy

We, "the name of the owner / operator of the drinking water system servicing ________________________" understand that supplying good quality drinking water is essential to the continued growth, prosperity, and well being of our citizens. We are committed to managing all aspects of our water system effectively to provide safe and aesthetically appealing water that tastes good and is free from objectionable colour or odour. It is our policy that the drinking water we provide will meet or exceed the quality provided by the Guidelines for Canadian Drinking Water Quality (or provincial / territorial drinking water quality guidelines or standards).

To achieve our goals we will:

- Cooperate with the provincial government to protect our water source from contamination.
- Ensure the potential risks associated with water quality are identified and assessed.
- Ensure that our water supply, treatment, storage, and distribution infrastructure is properly designed, constantly maintained, and regularly evaluated and improved.
- Include the drinking water quality and quantity priorities, needs, and expectations of our citizens, the provincial authorities, and our water system employees into our planning.
- Develop a mechanism to ensure adequate funds are available for the water utility to maintain and improve the infrastructure, implement best practices, and ensure our water treatment employees are educated about their responsibilities and adequately trained and certified.
- Establish regular verification of the quality of drinking water provided to our citizens and monitoring of the water treatment process that produce the water.
- Provide community awareness about the water supply and its management by establishing and maintaining effective reporting of the water quality and timely information about the water system to our citizens.
- Develop contingency plans and incident response capabilities in cooperation with provincial health authorities.
- Participate in appropriate research and development activities to ensure continued understanding or drinking water quality issues and performance.
- Participate in the drinking water guideline development and review process.
- Regularly assess our performance and continually improve our practices to produce good quality water.

We will develop a Drinking Water Quality Management System including an implementation plan to achieve these goals and adequately manage the risks to our drinking water quality.

All of our officials, managers, and employees involved with the supply of drinking water are responsible for understanding, implementing, maintaining, and continuously improving the Drinking Water Quality Management System.

Appendix B: Summary of Canadian Source Water Protection Measures

British Columbia
The provincial Drinking Water Protection Act was brought into force in May 2003. The Act protects drinking water through increased source and system protection, monitoring, assessments, infrastructure and certifications. In June 2002, the BC government established the Drinking Water Action Plan to ensure the delivery of safe drinking water. This plan includes a 'source to tap' approach to water protection in BC.

Existing groundwater monitoring measures include a network of 150 observation wells located throughout the province, as well as existing codes of practice for the testing, construction, maintenance, alteration and closure of wells. BC supports the use of GIS technology to map watersheds and groundwater supplies for current and future monitoring purposes.

Alberta
In 1948 Alberta adopted the use of the Green Area project. This policy directed the management of forested Crown lands in Alberta, an area encompassing about 52 percent of the province, and focused on a multiple-use management plan including: watershed protection, timber production, recreation, fish and wildlife protection, domestic grazing and mineral production. The most important lands of the Green Area, in terms of watershed protection, were the eastern slopes of the Rocky Mountains because they are the critical headwaters of the Prairie Provinces. The Rocky Mountain Forest Reserve was established in 1964 for the conservation of forests, and to maintain a clean, safe and secure water supply.

The current Alberta framework for water management planning includes regulations for drinking water quality standards, and guidelines for surface water quality. The recent updating of the provincial Water Act addresses many issues related to the protection and use of Alberta's water resources. The Water Act includes water licenses, protection of aquatic environments and deals with watercourse alterations and bulk water removal guidelines. In addition, the Environmental Protection and Enhancement Act includes areas of groundwater in its integrated approach to the protection of air, land and water. The use of GIS mapping has been implemented to catalogue and monitor groundwater resources.

Saskatchewan
As a result of the North Battleford inquiry, Saskatchewan has drafted a Water Management Framework to address measures for the protection of provincial water resources. This framework emphasizes the protection of water and wetlands, the management and development of water resources, and the inclusion of public involvement in decision-making processes. The planned Saskatchewan Watershed Authority Act will govern the Saskatchewan Watershed Authority in watershed planning, aquifer protection measures,

management of surface and groundwater supplies and monitoring. Existing legislation includes the Environmental Management and Protection Act, which regulates water pollution control measures, industrial effluent, and reservoir land use, and the Environmental Assessment Act, which requires proponents of development projects to receive Ministerial approval before proceeding with a development.

Saskatchewan's Rural Water Quality Advisory Program provides information and services to people in rural areas regarding water quality collection and testing, and surface and groundwater protection. The Prairie Farm Rehabilitation Association uses its expertise in the biological, geological, and engineering disciplines to develop secure water supplies, high water quality, and wastewater infrastructure in the prairies through programs such as the Rural Water Development Program and the Sustainable Well Water Initiative (PFRA 2001).

Manitoba
The Manitoba Water Quality Standards, Objectives and Guidelines were drafted in 2001, outlining recommended surface and groundwater criteria for various levels of legislative protection. Water quality standards are currently under development. A strategic planning framework for the protection of water resources in Manitoba includes a groundwater quality initiative for sampling and monitoring, a drinking water advisory committee, the development of drainage guidelines and water supply management. The Manitoba government is also in the process of developing a Nutrient Management Strategy for the derivation and implementation of nutrient limits in waters. Existing legislation pertaining to water protection and management in Manitoba include: the Environment Act, the Groundwater and Water Well Act, the Water Commission Act, the Water Resources Administration Act and the Water Rights Act.

Ontario
The Ontario government is in the process of implementing recommendations resulting from the Walkerton inquiry. In April 2003, the Advisory Committee on Watershed-based Source Protection Planning released its report - Protecting Ontario's Drinking Water: Toward a Watershed-based Source Protection Planning Framework. Its 55 recommendations set out a comprehensive framework that addresses: roles and responsibilities, the planning process, resources, timing and legislation. Guidelines for surface and groundwater Water Quality Objectives are also in place. There is an ongoing process of mapping surface and groundwater resources with the use of GIS technology. Groundwater monitoring programs are underway. The Environmental Protection Act prohibits contaminant discharges into the natural environment. Development of a Nutrient Management Act is also in progress which includes regulations for the protection of areas surrounding wellheads.

In Ontario, watershed management is supported by the Provincial Policy Statement and the Planning Act which supports a coordinated approach to address issues that cross municipal jurisdictions such as ecosystem and watershed related issues.

Quebec
Watershed management policies have been adopted and some regulations have been established. Groundwater protection has been addressed through the Regulation Respecting Groundwater Catchment, which is directed at groundwater resources intended for human consumption. The Regulation prevents excessive pumping by different users, and minimizes negative impacts from land use practices within the catchment on water plans and ecosystems.

The Regulation Respecting the Quality of Drinking Water sets guidelines for the control of water quality monitoring and management. The Regulation combines a strict monitoring plan with high water quality standards (bacteriological and physico-chemical), and requires operator certification at water treatment facilities to ensure high quality drinking water is provided to consumers.

In 2002, Quebec adopted a new water management policy in order to ensure the protection of its water resources and manage them sustainably, while protecting both public health and ecosystems. The province has also adopted a series of guidelines for water quality criteria of surface waters (MENVQ 2002).

For information on Quebec's Water Policy, see http://www.menv.gouv.qc.ca/eau/politique/index-en.htm

Nova Scotia
In October 2002, Nova Scotia released a Drinking Water Strategy which provides a comprehensive approach to the management of the province's drinking water. The strategy formally adopted the multi-barrier approach and forms a strong basis for protecting drinking water supplies. Under the strategy, source water protection plans are required for all municipal water supplies by 2005. The Environment Act provides for designating Protected Water Areas as one means of protection, and regulating activities which may impair water quality. Currently there are 24 designated Protected Water Areas. Several more designation requests are being processed as part of comprehensive water supply area management strategies. Municipalities are also able to protect water supply areas through municipal planning strategies and land use by-laws under the Municipal Government Act. In addition, the province has adopted a Statement of Provincial Interest on Drinking Water under the Municipal Government Act which requires municipalities to identify water supply watersheds in their municipal planning process and include strategies for their protection. Well Construction Regulations under the Environment Act are also in place to protect well water supplies and their surrounding aquifers. A number of guidance documents are available, including Designing Strategies for Water Supply Watershed Management in Nova Scotia. A detailed guide to developing a source water protection plan is currently in preparation.

New Brunswick
The province has adopted a comprehensive program for managing drinking water supplies from source to tap. In the area of source water protection, several orders and regulations exist under the provincial Clean Water Act. The Protected Area Designation Orders for watersheds and wellfields specify land uses in delineated areas surrounding these resources. At present, 21 watersheds

and 11 well fields are protected under these measures. The Water Classification regulation sets some raw water guidelines for all watersheds. Source water and raw water guidelines include the use of environmental and health-based standards. In addition, regulations require routine testing of source water intended for drinking and guidelines for well construction and watercourse alteration. Inventory and assessment of watersheds, wells and protected areas use GIS and other databases that integrate environmental, geographic and licensing information.

Newfoundland and Labrador
The province drafted a report in May 2001 outlining the current state of public water supplies and provided a framework for protection of public water supplies taking a multi-barrier approach. Several steps have been taken towards implementing these measures. In May 2002 the provincial government passed new legislation: the Water Resources Act and the Environmental Protection Act. The Water Resources Act addresses water protection and management largely through licensing procedures but also allows for specific designation of surface and groundwater supply areas. Water supply areas are monitored and evaluated through land use inventories, risk assessments and sampling, using diagnostic tools such as GIS. Approximately 250 water supply sources are currently protected. Use and activity within and around these areas is limited. Site-specific management plans have been developed for many watersheds.

The Water Resources Act allocates the designation of an area encompassing a source of public water supply as a Protected Water Supply Area. Most activities that could impair a water body are prohibited. Under the Municipalities Act cities can regulate some activities in watersheds such as sewage and sanitation. The Well Drilling Act requires that licensed operators drill all wells; ensuring proper wellhead protection measures are followed (Government of Newfoundland and Labrador 2001).

Prince Edward Island
Prince Edward Island relies exclusively on groundwater sources for drinking water. A drinking water strategy has been developed using a multi-barrier approach to safeguard the water supplies on the island. PEI has existing guidelines for the use of surface and groundwater supplies for agricultural irrigation purposes. A permitting process is employed for groundwater extraction and watercourse alteration. The Environmental Protection Act provides regulations on the construction, use and maintenance of wells, the discharge of contaminants, and requires the establishment of buffer zones adjacent to surface water systems. Long term water quality monitoring continues to be carried out in PEI in conjunction with the federal government under the Canada-PEI Water Annex to the Federal Provincial Framework Agreement for Environmental Cooperation in Atlantic Canada. Under this arrangement water quality is continuously monitored in 5 watersheds throughout the province. Groundwater levels are monitored continuously at 12 locations throughout PEI.

Territories
Management of water in the Yukon, NWT and Nunavut is currently under federal jurisdiction through the Department of Indian Affairs and Northern

Development (DIAND). However, territorial governments are responsible for providing safe and reliable drinking water. The Northwest Territories Waters Act and Regulations Act (1992) provides for the conservation and use of water that benefits the residents of the Northwest Territories (Department of Justice Canada 2001). The Mackenzie Valley Resource Management Act (1998) provides for an integrated system of land and water management in the Mackenzie Valley (Parliament of Canada 1998); this fulfills clauses of the Gwich'in and Sahtu land claims. It establishes Gwich'in and Sahtu Land and Water Boards in the Mackenzie Valley and a Mackenzie Valley Land and Water Board. The Mackenzie Valley includes all of the Northwest Territories, with the exception of the Inuvialuit Settlement Region and Wood Buffalo National Park. The NWT Public Health Act makes some provisions for the assurance of safe drinking water. Other indirect protection of water resources is provided by federal acts such as the Canadian Environmental Protection Act and the Fisheries Act.

Appendix C: Inventory of Potential Contaminants in Canadian Drinking Water Sources and their Origins

CATEGORY	CONTAMINANT	REASON FOR CONCERN	TYPICAL SOURCES
Physical			
	Colour	can be an indication of other contaminants	presence of coloured organic chemicals, metals or other contaminants
	Hardness - dissolved polyvalent metallic ions	aesthetic concerns	dissolution of metallic ions from minerals
	total dissolved solids	indication of the presence of other chemicals and contaminants	inorganic substances dissolved in water
	Turbidity	can be a source of nutrients for waterborne micro-organisms and can make disinfection of water more difficult	suspension of matter in water including, mineral particles, organic matter, organic compounds and microscopic organisms
Chemical - Organic			
	Benzene	Human carcinogen	used to manufacture other organic chemicals, present in gasoline, main source is vehicle emissions
	Benzo(a)pyrene	classified as probably carcinogenic to humans	formed during the combustion of fossil fuels and other organic matter
	Carbon tetrachloride	liver and kidney damage in humans, classified as probably carcinogenic to humans	used in the manufacture of other chlorinated hydrocarbons
	Monochloramines	classified as possibly carcinogenic to humans	by-product of chlorination of drinking water
	Chlorophenols	certain chlorophenols are classified as "probably carcinogenic to humans"	used in pesticide products or as wood preservatives
	Dichlorobenzene	classified as "probably carcinogenic to humans"	used in degreasing and paint removal formulations and deodorants
	1,2 – dichloroethane	classified as "probably carcinogenic to humans"	used in the production of vinyl chloride, used as a solvent, releases into water sources are from waste effluents and disposal of wastes
	1,1 dichlorethylene	classified as "possibly carcinogenic to humans"	used in food packaging industry, degradation product of tetrachloroethylene and 1,1,1 - trichloroethane
	Dichloromethane	classified as "possibly carcinogenic to humans"	used as an industrial solvent for paint stripping, as a degreasing agent and as an aerosol propellant
	Monochlorobenzene	classified as "possibly carcinogenic to humans"	solvent in adhesives
	Tetrachloroethylene	classified as "possibly carcinogenic to humans"	used as a solvent in dry cleaning and metal cleaning
	Toluene	effects on the central nervous system	used as solvents, gasoline additives, used in the manufacture of other chemicals

CATEGORY	CONTAMINANT	REASON FOR CONCERN	TYPICAL SOURCES
	Ethylbenzene	effects on the central nervous system	used as solvents, gasoline additives, used in the manufacture of other chemicals
	Xylene	effects on the central nervous system	used as solvents, gasoline additives, used in the manufacture of other chemicals
	Trichlorethylene	acute exposure has effects on the central nervous system	used for metal degreasing
	Trihalomethanes	one of the trihalomethanes, chloroform has been classified as "probably carcinogenic to humans"	formed from the chlorination of dissolved organic matter
	vinyl chloride	carcinogenic to humans and animals	used in the manufacture of polyvinyl chloride, releases are from industrial discharges
Chemical - Inorganic			
	Ammonia	indication of a potential source of nitrates	degradation of nitrogenous organic matter, industrial and municipal waste discharges
	Chloride	high chloride levels result in unpleasant taste	dissolution of natural salt deposits, dissolution of road salt
	Cyanide	highly toxic to humans at high dosages	mining and industrial effluents
	Fluoride	ingestion of large amounts results in mottling of tooth enamel	manufacture of phosphate fertilizers and bricks, dissolution of natural minerals containing fluoride
	nitrate/nitrite	leads to methaemoglobinaemia in infants	from fertilizers
	nitrilotriacetic acid	has been shown to caused tumours in studies in rats, no adverse effects on humans have been observed	used in laundry detergents to replace phosphates
	Sulphate	ingestion of large amounts can lead to gastrointestinal illnesses	dissolution of sulphate containing minerals, used in chemical, dye and fertilizer manufacturing, mining, pulp and paper industry, atmospheric sulphur dioxide
Chemical - Metals			
	Arsenic	toxic and carcinogenic to humans	used in hide tanning processes, found in pesticides, additives and pharmaceuticals, natural sources are the dissolution of arsenic minerals
	Barium	soluble barium salts are acutely toxic	used in industrial application including electronics, plastics, rubbers, textiles and oil and gas
	Boron	acute boron poisoning can result in nausea, diarrhoea, vomiting, headaches, skin rashes and central nervous system effects	used as an insecticide and disinfectant, and as an anti-oxidant in soldering
	Cadmium	ingestion causes vomiting and gastrointestinal illnesses, chronic ingestion leads to renal disease and softening of the bones	effluent releases from industrial operations using cadmium
	Chromium	trivalent chromium is non-toxic however it can be oxidized to hexavalent chromium, studies on animals have shown toxic effects on the kidneys, liver and gastrointestinal tract	effluents from industries where chromium is used in processes (i.e., metal plating)
	Copper	adverse health effects at high doses	used in the production of electrical wire, manufacture of alloys, and in pesticide formulations

CATEGORY	CONTAMINANT	REASON FOR CONCERN	TYPICAL SOURCES
	Lead	classified as "possibly carcinogenic to humans", has been shown to have effects on the central nervous system	used in manufacture of lead acid batteries, pigments, chemicals and solder
	Mercury	mercury poisoning results in renal and neurological disturbances	dental amalgam
	Uranium	causes nephritis in humans and animals	dissolution of natural uranium deposits, release from mill tailings and phosphate fertilizer
Chemical - Pesticides			
	Aldicarb and metabolites	can cause dizziness, weakness, nausea and diarrhoea in humans	used as an insecticide on agricultural crops
	Aldrin and dieldrin	shown to have effects on the central nervous system and liver in experimental animals	used as an insecticide on agricultural crops
	atrazine and metabolites	classified as possibly carcinogenic to humans	used as a herbicide for corn and rapeseed crops
	azinphos-methyl	studies on rats and dogs have shown effects on cholinesterase activity	insecticide used for fruit, forage, vegetable and grain crops
	Bendiocarb	studies of bendiocarb in rats showed effects on white blood cells, serum cholesterol levels and brain cholinesterase levels	used as an insecticide in food storage and handling and in agriculture
	Bromoxynil	studies in rodents showed effects of increased liver and kidney weights, thyroid enlargement and reduced liver/body weight ratios	used to control broad-leaved weeds in grain crops
	Carbaryl	inhibits cholinesterase activity	insecticide used on fruit, vegetable and cotton crops
	Carbofuran	cholinesterase inhibitor	insecticide and nematocide used on fruit and vegetable crops
	Chlorpyrifos	cholinesterase inhibitor	insecticide use to control mosquitoes, flies, household pests and aquatic larvae
	Cyanazine	studies of the health effects on rats showed reduces kidney weight and increased liver rates	herbicide used for weed control of corn, rapeseed and mixed grain crops
	Diazinon	cholinesterase inhibitor	insecticide used to control household and soil insect pests
	Dicamba	studies on animals have shown toxic effects on the liver	herbicide used for weed control on grain crops and pastures
	2,4 – dichlorophenoxyacetic acid	classified as "possibly carcinogenic to humans"	herbicide used to control broadleaf weeds on cereal cropland and on other noncropland areas (i.e., lawns, pastures, industrial properties)
	Diclofop-methyl	studies on animals have shown toxic effects on the liver	used to control grasses in grain and vegetable crops
	Dimethoate	cholinesterase inhibitor	insecticide used on fruit, vegetable, field and forestry crops
	Dinoseb	very toxic to humans, has teratogenic and phototoxic effects	herbicide used to control weeds in cereals, peas, bean and strawberry crops
	Diquat	toxic effects to humans include damage to the gastrointestinal tract, brain, liver, kidneys and lungs	desiccant for seed crops

CATEGORY	CONTAINANT	REASON FOR CONCERN	TYPICAL SOURCES
	Diuron	toxic effects include weight loss and abnormalities of the blood, liver and spleen	used to control weeds in non-crop areas
	Glyphosphate	studies on rodents have shown liver and kidney effects	herbicide for non-selective weed control
	Malathion	acetylchlorinesterase inhibitor	insecticide used to control mosquitoes and flies
	Methoxychlor	studies on rats showed reduced growth but no other effects, studies on humans have not shown any other adverse effects	insecticide used on fruits and vegetables
	Metolachlor	some reports of skin allergies, no other adverse effects identified	herbicide used on corn, bean and soybean crops
	Metribuzin	studies of dogs showed reduction in weight gain and increase in thyroid, kidney, spleen and liver weights	weed control on agricultural crops
	Paraquat	can case respiratory effects and effects on the kidneys and nervous system in humans	herbicides used on aquatic weeds, seed crop and orchids and on
	Parathion	cholinesterase inhibitor	insecticides used to control insects on agricultural crops
	Phorate	cholinesterase inhibitor	insecticide used on agricultural crops
	Picloram	studies on rats showed effects on the kidneys and liver	herbicide used on non-crop land, rights-of-way, pastures,
	Simazine	no studies have been done on the effects on humans, studies on dogs showed high levels of simazine ingestion resulted in lower body weights	herbicide used for weed control on agricultural crops
	Terbufos	acetylcholinesterase inhibition	insecticide used on corn, sugarbeet and rutabagas crops
	Trifluralin	effects on studies of rodents were decreased body weights, increased liver weights and renal toxicity	herbicide used in cereal, grain and vegetable crops
Biological - Bacteria			
	Escherichia coli	the O157:H7 strain of *E. coli* results in gastrointestinal illness in humans, infection can be life-threatening to sensitive populations	human and animal wastes
Biological – Protozoan parasite			
	Cryptosporidium	pathogen that infects the small intestine of humans and other mammals and causes gastrointestinal illness	wastes from wild and domestic animals
	Giardia lamblia	'beaver fever' causes gastrointestinal illness, headaches and fever and can be fatal to those with compromised immune systems	wastes from wild and domestic animals
	Toxoplasma gondii	toxoplasmosis causes flu-like illness, congenital damage in the fetuses of pregnant women	domestic and wild cat feces

Appendix D: Case Studies of Water Management Approaches in Canada

Case Study 1: Vancouver, British Columbia

Subject: WATERSHED ASSESSMENT (With GIS Technology)

The Greater Vancouver Regional District (GVRD), a partnership of twenty-one municipalities and other communities in the Greater Vancouver area, provides community water supplies its member municipalities. The water supply is obtained from three watersheds, the Coquitlam, Seymour and Capilano Watersheds, located to the north of the GVRD area. Watershed management, in conjunction with water treatment, is an important aspect of drinking water protection.

In the early 1990's the GVRD began using GIS technology to map the characteristics of the three watersheds. GIS data on the topography, surficial geology, and soils can be obtained from the GVRD website. This data is used to identify and assess potential threats to water, as well as to forecast water supply and availability. This assessment will subsequently be used to develop watershed management plans for the protection of water resources.

For more information on the Greater Vancouver Regional District Watershed Management Plan, please visit the following website:
http://www.gvrd.bc.ca/services/water/sheds/default.html

Case Study 2: Kelowna, British Columbia

Theme: CREATING WATERSHED PARTNERSHIPS

The City of Kelowna case study illustrates a few innovative approaches at establishing various levels of partnerships within a watershed.

The City of Kelowna is serviced by five different water utilities, each water utility obtains water from a different source within the regional watershed. Two of the water sources are primarily used for domestic purposes and the remaining three sources are primarily used for agriculture. In 1991, the Kelowna Joint Water Committee was formed to establish co-operation between the five utilities. The City of Kelowna, the Rutland Water District and the Kelowna Joint Water Committee have all been involved in water protection activities. The City of Kelowna, and to a lesser extent, the Kelowna Joint Water Committee have been involved in watershed assessment activities.

In 1995, the City of Kelowna's adopted planning policies that have both direct and indirect impacts on watershed protection. These policies include general environmental policies and stream protection corridor policies. To facilitate the implementation of the planning policies, the Council of the City of Kelowna established a Watershed Committee for development of a watershed management and action plan for the creeks flowing through the City of Kelowna in 1997. Under the direction of this committee, the City of Kelowna has engaged in a number of watershed assessment and protection activities that involve a number of stakeholders.

For more information on Kelowna's Watershed Stewardship Program, please contact the City of Kelowna: http://www.city.kelowna.bc.ca/

Case Study 3: Kamloops, British Columbia

Theme: LAND USE PLANNING TO PROTECT WATER QUALITY

The Region of Kamloops case study demonstrates the use of land use planning for the protection of the South Thompson River, the drinking water source for the City of Kamloops.

In 1992 the Province of British Columbia issued a Provincial Land Use Charter. This charter outlined two commitments: 1) protecting and restoring the quality and integrity of the environment, and 2) securing a sound and prosperous economy for present and future generations. The charter outlined principles in the areas of sustainable environment, sustainable economy, decision-making processes, aboriginal peoples, and shared responsibility.

The Region of Kamloops was the first region within the Province of British Columbia to develop and implement a *Regional Land and Resource Management Plan*. The framework for the plan was begun in 1989 and the plan was implemented in 1995. The plan is a regional plan that assesses and provides for land use planning, and by extension watershed protection, within the Regional watershed area, including the City of Kamloops. The *Regional Land and Resource Management Plan* provides for the development of local land use planning by local governments within the region.

The regional plan included an examination of the physical, social and economic characteristics within the region, followed by an assessment of the land use within the regional area. These areas were then categorized into designated Resource Management Zones within the region. Several categories of Resource Management Zones exist, each carrying their own specific management principles based on protective objectives.

The City of Kamloops, whose drinking water supply is managed separately from the LRMP, implemented a local land use plan in 1997. One of the goals of this plan is to "protect/enhance the natural environment". The plan identifies significant environmental areas within the City of Kamloops including riparian habitat and ponds, lakes or streams. Various protective mechanisms for significant areas are identified in the plan. These include legal (i.e., environmental protection laws, and permits) and other mechanisms (acquisition of significant lands, provision of buffering areas), all of which have had the indirect effect of protecting their drinking water source, and improving their drinking water quality.

For more information on the region's land use program, see the webpage of Kamloops' LRMP: http://srmwww.gov.bc.ca/sir/lrmp/kam/

Case Study 4: Shoal Lake, Manitoba

Theme: USING THE WATERSHED PROTECTION APPROACH TO PROTECT SOURCE WATER

The Shoal Lake case study demonstrates an unusual case where the source water for a city is obtained from another watershed, the majority of which is located in another province. Cooperation between provincial and municipal governments allowed for the development of a watershed plan from multiple users in different jurisdictions (federal, provincial and First Nations). The Shoal Lake Watershed Working Group (SLWWG) was formed to develop and address the recommendations in the watershed plan. The plan allowed for the continued use of the water resource, which includes a safe drinking water supply.

Based on the watershed assessment, the SLWWG developed a watershed management plan over a two-year period. Source water protection was a focal point of the overall watershed management plan because the city of Winnipeg, as well as many First Nations tribes, draw their drinking water from Shoal Lake. The stakeholders and the Working Group developed goals, objectives, and water quality protection strategies that included pollution prevention, best management practices plan, wastewater treatment upgrades, solid waste reduction and management, and enhanced monitoring. Based on a thorough ranking of the threats to Shoal Lake, they were able to prioritized their actions

For more information on the Shoal Lake Management Plan, please visit the following website: http://www.gov.mb.ca/conservation/ShoalLakeWMP/

Case Study 5: Quebec City, Quebec

Theme: ASSESSING POTENTIAL THREATS

In January 2002, Quebec City and thirteen surrounding municipalities were amalgamated into one city. One of the problems faced by the new city is the provision of a steady supply of good quality drinking water to meet the needs of the residents.

An assessment the current water supplies for the new city was conducted (Problématique de l'approvisionnement et de l'utilisation de l'eau potable dans la nouvelle ville de Québec January 2002). The assessment noted most of the drinking water supply in the area were from surface water sources with a small portion being supplied by groundwater. The study noted two significant threats to source waters: 1) certain water supply systems were not able to meet demands at peak periods, and 2) various localized chemical threats to source waters, such as TCE.

As a result, municipalities within the Quebec City region have implemented an integrated watershed management plan. This plan conceived a number of watershed protection initiatives such as the adoption of a policy for sustainable use of drinking water resources, land-use planning (i.e. zoning to protect water quality), water quality regulations and public education to encourage low impact activities to minimize water consumption.

For more information on the integrated watershed management plan for the Québec City region, please visit the following website: www.inrs-eau.uquebec.ca/publications/r610.htm

Case Study 6: Pockwock-Bowater Watershed, Nova Scotia

Theme: INDUSTRIAL PARTNERSHIPS / WATERSHED MANAGEMENT

The Pockwock-Bowater Watershed Project (PWP) is an on-going forestry-based ecosystem research project. The primary objective of the PWP is to generate data on the response of stream water (quality and quantity) to varying forestry management activities. This is of particular importance since the Pockwock watershed serves as the primary drinking water supply for Halifax. The study will also examine the effect of these forestry practices on nutrient export to the watershed.

Analysis and results of the project are still forthcoming, but the information gathered will be utilised to evaluate the effectiveness of forestry management activities alongside water bodies within watersheds. It is hoped that the information will be applied to future watershed management practices, as well as providing insight into factors affecting source water quality of a municipal water supply.

For more information on the Pockwock-Bowater Watershed Project, please visit the following website: *http://www.novaforestalliance.com/pbws/*

Case Study 7: Development of Well-Field Protection Plans on Prince Edward Island

The Province of Prince Edward Island (PEI) depends completely on groundwater as a source for drinking water, and approximately 45% of the population is serviced by municipal water supply systems. The Province has long recognized the need for source water protection for these systems. Because of the relatively uniform hydrogeological and land use conditions in PEI, it is believed that the development of a generic approach to the protection of municipal well-fields in the Province as a whole would assist in the implementation of better source water protection.

In June 2001, the Government of PEI announced a ten-point strategy for the protection of drinking water quality for private and public water supplies across the Island. A central theme in this strategy was the adoption of a multi-barrier approach to drinking water protection. One of the key elements for the protection of municipal drinking water supplies was the development of a new set of Regulations governing the operation of municipal water supply and wastewater treatment systems.

These new Regulations will set out mandatory requirements for water quality monitoring, operator certification and well field protection. Under these Regulations, municipalities will be required to develop well field protection plans, submit them for provincial approval, and implement them by the spring of 2004. While each municipality will have some flexibility in how it designs and implements its well field protection plan, the intention is that plans will be based on the approach outlined in the drinking water strategy with respect to how protection zones will be delineated and what types of land use issues will be addressed. The Province intends to work cooperatively with communities on this initiative. Communities will be responsible for land use inventories within protection zones and in collaboration with the province, identify non-conforming land uses, and suitable mitigative measures.

For more information on PEI Well Field Protection plans, please contact the PEI local authorities. Contact information and general information on their drinking water strategy can be accessed through their website: http://www.gov.pe.ca/infopei/onelisting.php3?number=50234

Appendix E: Municipal Governments and the Protection of Source Waters

The Federation of Canadian Municipalities (FCM) has produced a document entitled *Municipal Governments and the Protection of Water Sources.* The document explicitly focuses on municipal government and is written for municipalities. It includes resources so municipalities can obtain additional information. This appendix summarizes the content of the FCM document.

Throughout the Source to Tap document, guidance on how to protect water sources as part of a multi-barrier approach to providing safe drinking water is given and special reference is made to the role of municipalities. They are listed as partners in source protection, sources of information, potentially sources of funding, and active players in watershed protection.

Municipal government has made a significant investment throughout Canada in the delivery of water to communities. This document outlines the type of actions that municipal governments can take immediately to protect watersheds and water sources. It is directed to both elected representatives and staff. It draws on initiatives already taken by municipal governments throughout Canada. While provincial and federal frameworks are important and their respective roles have been identified in some detail elsewhere in this document, it is at the municipal level that significant improvement can be made. Municipalities know their local area and issues. They can act as a catalyst to engage their community, and can identify significant opportunities and act to protect their water sources.

The maintenance and improvement of source water quality is an investment that more municipalities will be taking in the future. This will be particularly important as the onus on municipal politicians and staff increases under the legal changes foreshadowed, for example in Ontario. The concept of 'statutory standard of care' increases the obligations of municipal councillors to ensure effective oversight of the operation of municipal waterworks. This is likely to include all elements of the provision of drinking water, including source protection.

Source water protection can include difficult political decisions that may well restrict individual activities and the 'right' to use land (or water) as people have been used to. In addition there can be well-entrenched industrial activities (including agriculture) that have traditionally had precedence. A challenge for some municipalities will be to provide a high priority to water quality protection.

A number of municipalities have already undertaken the full range of activities described here. Not all of the options will be suitable for every municipality, but are offered as starting points for selecting different options.

The suggestions in this document have drawn from individual municipalities, municipal websites and publications, water authority websites and newsletters, as well as submissions and commissioned papers to the Walkerton Inquiry and other water investigations. In addition, papers from recent water quality conferences were identified, with additional assistance provided by the Federation of Canadian Municipalities, individual municipalities and organizations such as the Association of Ontario Municipalities and Conservation Ontario.

For more information on the contributed document from FCM, please contact the National Guidelines and Standards Office, Environment Canada.

Appendix F: Municipal Waste Water Treatment and the Multi-Barrier Approach

The Canadian Water and Wastewater Association has written a document titled: Municipal WasteWater Treatment – Its Role in the Source to Tap Framework. This appendix summarizes the content of that document.

Generally, wastewater management and wastewater treatment levels achieved in Canada require improvement. Notwithstanding the fact that municipal wastewater effluent impacts on the environment are well documented, direct impacts on drinking water needs to be further investigated (e.g., pharmaceutical effects). Environmental water quality management, however, must also weight in other land use practices that have point source discharges such as the mining and pulp and paper sectors which can tax the receiving environment. Land use practices with non-point source discharges cause a greater challenge and include, for example, forestry and agriculture.

Wastewater total quality management is implicit in the source to tap approach and addresses management and treatment of public wastewater "back to the source". As such, municipal wastewater treatment is traditionally considered to be the final phase of municipal management of water services. These services commence with the removal of water from a source, then this water passes through a treatment system to remove contaminants and render it potable, is then distributed to customers through a network of water mains and subsidiary distribution systems for delivery to the point of consumption, where it is then used by the customers and the waste water discharged to waste water collection systems for and return to a wastewater treatment plant where it is treated prior to discharge back to the environment. In many areas, there are similar but private systems involving a well, some point-of-entry treatment systems, use and collection and return to the environment following on-site treatment.

Approximately 24 million Canadians are connected to central (municipal) water and waste water services while the remaining 7 millions are on private systems. Millions of Canadians also use from time to time, community and other private water and waste water systems outside municipal service areas. The municipal collection of waste waters may also involve the collection of storm water through a collection system which is often linked with or part of the sanitary wastewater collection system of the municipality. Municipal systems will also collect non-sanitary wastewaters from industry and commercial activities resident within their jurisdictions, often containing chemical wastes. The two systems (municipal and private) are linked in that the solids accumulating in the private on-site treatment systems are removed periodically and delivered to a municipal wastewater treatment plant for further treatment prior to discharge to the environment. Industrial wastewaters may also be generated and discharged to the environment on private systems not connected to municipal systems, whether or not located within a municipality. Additional information on municipal waste water treatment, residential on-site waste water treatment and storm water management is given in the CWWA document

For more information on the contributed document from CWWA, please contact the National Guidelines and Standards Office, Environment Canada.

Appendix G: Descriptions of Backflow Prevention Devices

There are five distinct types of backflow prevention devices and a number of subtypes which are designed to protect against specific types of hazards. The degree of hazard must be assessed along with the type of cross-connection present to determine which type of backflow prevention device is suitable for the situation.

<u>Air Gap (AG)</u>

An AG is a physical separation of the supply pipe by at least two pipe diameters vertically above the flood rim of the basin to protect against both backsiphonage and backpressure. An AG device is suitable in non-pressurized plumbing settings.

<u>Atmospheric (non-pressure) Type Vacuum Breaker (AVB)</u>

The AVB is always placed downstream from all shut-off valves and must always be installed at least 15 cm (6 inches) above all downstream piping and outlets to prevent backsiphonage only, not backpressure. An AVB must not be used for more than twelve (12) out of any twenty-four (24) hour period.

<u>Pressure Vacuum Breaker (PVB)</u>

The PVB includes a check valve which is designed to close with the aid of a spring when flow stops. It also has an air inlet valve which is designed to open when the internal pressure is 7 kPa (1 psi) above atmospheric pressure to prevent so no contaminant can be siphoned back into the potable water system. The PVB must be installed at least 30 cm (12 inches) above all downstream piping and outlets. It may only be used to protect against backsiphonage. It is not acceptable protection against backpressure.

<u>Double Check Valve Assembly (DCVA)</u>

The Double Check Valve Assembly comprises two internally loaded, independently operating check valves together with tightly closing resilient seated shut-off valves upstream and downstream of the check valves. This device assembly is suitable for protection against either backsiphonage or backpressure.

<u>Reduced Pressure Principle Assembly (RP)</u>

This assembly comprises two internally loaded independently operating check valves and a mechanically independent, hydraulically dependent relief valve located between the check valves. This is to be installed horizontally and used to protect against either backsiphonage or backpressure.

Double Check Detector Assembly (DCDA)

The DCDA comprises a line-sized double check valve assembly with a specific bypass meter and meter-sized double check valve assembly. This assembly is used when the protection of a double check valve assembly is required, yet where the added requirement of detecting any leakage or unauthorized use of water exists.

Reduced Pressure Principle Detector Assembly (RPDA)

The RPDA is very similar to the double check detector assembly except that the RPDA is designed for situations requiring the protection of a reduced pressure principle assembly and detection of unauthorized use of water or leaks. This assembly is normally used on fire lines which may contain contaminants, such as anti-freeze additives.

Appendix H: Procedures for Flushing and Pipe Cleaning

The following procedures are recommended for flushing operations.

- Pre-plan an entire day's flushing using the available distribution system maps. Consider flushing at night between midnight and 5:00 a.m. to minimize completing water demand and any inconvenience to customers.
- Determine where sections of mains are to be flushed at one time, the valves to be used, and the order in which the pipelines will be flushed.
- Start at or near a source of supply and work outward into the distribution system. Progress from large mains to small mains. Generally it is not practical to flush mains larger than 60 cm or 24 inches. Record which wells are on-line or isolated.
- Assure that an adequate amount of flushing water is available at sufficiently high pressures, that is, ensure the reservoir(s) are full. A minimum flushing velocity of 2.5 ft/sec (5 ft/sec preferred) (0.75 and 1.50 m/sec) should be used.
- Prior to flushing the mains, notify all customers who will be affected of the dates and times of the flushing through billing, newspapers, and local radio and TV announcements. Individually notify people who might be on dialysis machines and also hospitals, restaurants, laundromats, and others who might be affected while the mains are being flushed.
- Isolate the section to be flushed from the rest of the system. Close the valves slowly to prevent water hammer.
- Open the fire hydrant or blowoff valve slowly.
- Direct flushing water away from traffic, pedestrians, and private lots.
- Open hydrant fully for a period long enough (5 to 10 minutes) to stir up the deposits inside the water main.
- Assure that system pressures in nearby areas do not drop below 138 kPa (20 psi).
- Record all pertinent data (such as valve and hydrant condition) regarding the flushing operation as well as a description of the appearance and odour of the water flushed.

- Collect two water samples from each flowing hydrant, one about 2 to 3 minutes after the hydrant was opened and the second sample just before closing the hydrant. These samples allow a check on the water quality for certain basic water quality indicators (iron, chlorine residual, turbidity).

- After the flushing water becomes clear, slowly close the hydrant or blowoff valves.

- In areas where the water does not become completely clear, the operator should use judgment as to the relative colour and turbidity and decide when to shut down.

- Mark closed valves on a map or flushing sheet (see Flushing Procedures) when they are closed and erase marks after the valves are reopened.

- After one section of pipe has been flushed, move onto the next section to be flushed and repeat the same procedures.

Pipe Cleaning

Mechanical cleaning devices are often used to clean pipes if flushing does not provide relief from water quality problems or from problems in maintaining the carrying capacity. Foam swabs, pigs, and air can be used to remove loose sediments and soft scales from mains. Pigs can be used to flush new mains prior to disinfection. Scrapers or brushes can be used in mains with hardened scales or extensive tuberculation, but are usually used prior to relining. Of the available devices, foam swabs and pigs are the easiest and most effective to use. Pipe cleaning projects should produce improved pipe carrying capacity and a reduction of power (and cost) to pump the water.

Swabs are typically made of polyurethane foam; both soft and hard grade forms are available. All swabs inserted in mains must be retrieved. Pigs are also made of polyurethane foam, but are much heavier in weight, harder, and less flexible than swabs. They are bullet-shaped and come in various grades of flexibility and roughness.

Generally, if loose sediments and soft scales in the pipe are to be removed without disturbing hardened incrustations, swabs are use. To improve the carrying capacity of the main, then pigs should be used. The use of pigs is more likely to result in leaks at a later date.

A mixture of air and water can effectively clean small mains up to 100 mm (4 inches) in diameter. Air is introduced into the upstream end of the pipe from a compressor of the same type used for pneumatic tools. Spurts of water mixed with the air can remove all but the toughest scale.

The use of compressible foam swabs and pigs provides flexibility in their insertion and removal. The entry and exit points used for smaller size mains are fire hydrants, air valves, blowoffs, wyes, and tees. In larger mains, a section of pipe may be removed and a wye inserted in its place as the entry and exit points to allow insertion, launching and exiting of the swabs and pigs.

The routine procedures used for cleaning pipe are very similar to those used for flushing except that services to customers will have to be shut off during cleaning. A typical main cleaning includes both flushing and swabbing operations which usually start near the beginning of the system and move outward toward the ends of the system.

The swab should pass through the main at a speed of 0.6 to 1.2 m/sec (2 to 4 ft/sec). Using velocities in this range, up to 1,200 m (4,000 feet) of pipe can be effectively cleaned before the swab wears down to a size smaller than the main. The entire operation may require 10 to 20 swabs. Typically, 2 to 3 runs are made using 4 to 5 swabs in each run. The cleaning should continue until the water behind the swabs emerging at the exit clears up within one minute. All swabs inserted into and ejected from the main must be accounted for.

Before starting any cleaning job, determine how to dispose of or remove the water and deposits discharged from the cleaned water main. If the water is discharged onto a street or the ground, be certain the drainage is proper and adequate.

The procedures to follow for cleaning a water main using pigs or swabs are as follows:

- Isolate the line to be cleaned. Be sure that those customers requiring temporary services have enough water.
- Be sure that all valves in the section to be cleaned are fully opened.
- Turn on the water and verify the direction of flow.
- Run a full-sized bare swab through the main to prove the direction of flow.
- Run a swab unit through the main. Measure the diameter of the unit upon exiting and introduce a crisscross type unit into the main that will just fit the "true" opening. Run a full-sized bare swab behind the crisscross unit to assure a tight seal. Continue this process until a unit is discharged from the main in reusable condition.
- Increase the size of the crisscross pigs in one-inch increments until the units that measure the same as the pipe inside diameter are being used. For pipes with a build-up of hard scale, such as carbonates, crisscross wire pigs can be used on the final pass.
- Run a full-sized bare swab to sweep out any loose debris.

To obtain the best possible cleaning results, be sure to:

- Flush thoroughly after each pig run.
- Avoid applying more than two wire-brush pigs on the final pass (this prevents overcleaning).
- Launch the pigs from fire hydrants for mains of 8 inches (200 mm) or smaller, or from concentric reducers, pipe couplings, spools, eccentric reducers, in-line launchers, or by hand.
- Have an operator with experience in proper main cleaning procedures help you the first time you attempt to clean a main. This is a good practice to avoid stuck, lost or damaged pigs or swabs.
- After the cleaning operation is completed, flush and disinfect (chlorinate) the main. When the main is reactivated, flush service lines and remove any temporary services.

For more information on flushing and pipe cleaning, see "Guidance Manual for Maintaining Distribution System Water Quality", AWWARF (2000), Report Number ISBN 1-58321-074-1

Appendix I: Procedures for Inspecting and Maintaining Valves and Hydrants

Procedures for valves

Routine valve inspections should be conducted by performing the following tasks:

- Verify the accuracy of the location of the valve boxes on the system map (if incorrect, change the map and update the Master Copy).
- After removing the valve box cover, inspect the stem and nut for damage or obvious leakage.
- Close the valve fully and record the number of turns to the fully closed position. Always close a valve slowly to prevent water hammer.
- Reopen the valve to re-establish system flows.
- Clean valve box cover seat. Sometimes covers on valve boxes will come off when traffic passes over them due to dirt in the seat.

Exercising (opening and closing a valve) should be done at the same time the valve inspection is made. Some manufacturers recommend that a valve stem never be left in a fully open or closed position. They recommend that after fully opening or closing a valve, back off the stem by one turn.

Conditions of each system will determine how often the valves should be exercised, in general, it is recommended that all valves be exercised at least once a year. Planned exercising of valves verifies valve location, determines whether or not the valve works, and extends valve life by helping to clean incrustations from the valve seats and gates. Any valves which do not completely close or open should be replaced. Valves which leak around the stems should be repacked. To determine that a valve is closed, an aquaphone or other listening device can be used. Valves should be exercised in both directions (fully closed and fully opened) and the number of turns and direction of operation recorded. Valves operating in a direction opposite to that which is standard for the system need to be identified and this fact recorded. The condition of the valve packing, stem, stem nut, and gearing should be noted. A timely maintenance program should be initiated to correct any problems found during the inspection and exercising.

An important factor in maintaining distribution system valves are the availability of current and correct maps of the distribution system. Each utility should verify their maps often so that it is accurate, and keep the map up to date by immediately recording any changes such as replacements or additions.

Some water purveyors equip their service trucks with "gate books" which carry all of the pertinent valve information including location, direction of turning to close, and number of turns required.

Maintaining current records is as important as maintaining current maps. A purveyor should develop a valve form to track important information. The location of a valve is obtained from a controlled survey bench mark or permanent reference point. The make of valve is important because different makes have different operating characteristics. The use of a simple valve numbering system keyed to up-to-date drawings is recommended. This procedure has proven to be quite helpful in locating valves rapidly and in communicating with others about particular valves.

Road improvements require constant attention from water distribution system operators to ensure that valves are not lost. Valve boxes can be graded out or covered with pavement. The centre lines of roads, curb lines, and right-of-way lines are not to be used as reference points for locating valves, because they can change over time.

Valves left closed in error can cause severe problems in a distribution system. Construction and maintenance crews operate valves as they do their work, and contractors and plumbers may operate valves without permission. Separate pressure zones in distribution systems may be established by closing valves, thus increasing the possibility of problems related to the incorrect use of valves. Unexplained problems with pressure and excessive operation of pumps in a given area have been traced to valves left closed or open in error. When crews change shifts during a project, valve closure and opening information must be exchanged. Crew chiefs must be certain all valves are restored to proper positions.

Proper advance planning is important. The valves that will be used to isolate a damaged valve must be in good operating condition. When ordering repair parts, include the size, make, direction of opening, year of manufacture, and other pertinent information in order to assure that the correct repair parts will be received.

Until the valve is isolated and opened up, it is difficult to determine what part of the valve is damaged. Therefore, have all replacement parts available before isolating the necessary section of the water main, excavating the valve, and making the repairs.

Procedures for Fire Hydrants

Operators responsible for hydrant inspections should be familiar with the various types of hydrants used in their system. There are two basic types of fire hydrants, the dry barrel and wet barrel. A hydrant has four principal parts: the inlet pipe which is connected to the main water supply, the main valve, the barrel and the head. The supplier should be contacted whenever necessary to obtain descriptive literature, operation and maintenance instructions, parts manuals or assistance on particular problems.

In general, fire hydrants should be inspected and maintained twice a year. These operations are often done in the spring and the fall. However, each hydrant should also be inspected after each use. Inspect dry-barrel hydrants after use, especially during freezing weather, to assure that the drain remains open when the hydrant is not in use.

An additional source of information on fire hydrants is AWWA's Manual M17, Installation, Field Testing, and Maintenance of Fire Hydrants. Some general inspection and maintenance procedures used for hydrants include:

- Inspect for leakage and make corrections when necessary.
- Open hydrant fully, checking for ease of operation.
- Flush hydrant to waste (take care to direct flow).
- Remove all nozzle caps and inspect for thread nozzle and cap threads. Clean and lubricate outlet nozzle threads.
- Replace caps, tighten with a spanner wrench, then back off on the threads slightly so that the caps will not be excessively tight but will leave sufficient frictional resistance to prevent removal by hand.
- Check for any exterior obstruction that could interfere with hydrant operation during an emergency.
- Check dry-barrel hydrants for proper drainage.
- Clean exterior of hydrant and repaint if necessary.
- Be sure that the auxiliary valve is in the fully opened position.
- If a hydrant is inoperable, tag it with a clearly visible marking and immediately report the condition of this fire hydrant to your fire department.
- Prepare a record of your inspection and maintenance operations and any repair work.

Hydrants can be partially protected against freezing by covering them with a box which can be quickly removed when the hydrant must be used. To keep hydrants from freezing (those that won't drain in the winter due to frozen conditions), insert in the hydrant propylene glycol or some other non toxic NSF approved substance that won't freeze or cause water quality problems. Frozen hydrants may be thawed using electric current thawing or live steam injected through a hose into the hydrant barrel.

Standardization of hydrants minimizes the requirement for stocking parts, simplifies repair procedures, and allows replacing only defective parts. Every water purveyor should keep a basic stock of repair parts on hand for immediate use.

Fire hydrants are usually the only part of the distribution system regularly seen by the general public. Frequent painting of hydrants creates a favourable impression and is, therefore, a public relations tool. Fire hydrant caps or guards can be installed on the tops of fire hydrants to eliminate fire hydrant vandalism.

Appendix J: Locating and Remediating Line Breaks

Breaks in water mains can occur at any time and every purveyor must have an established, written response plan. After a break has been located, determine which valves must be closed to isolate the break. A good policy before shutting off any valves is to notify every consumer involved that they will be out of water for an estimated length of time. The purpose of this advance notification is to allow consumers to make any necessary preparations. If extensive damage is caused by the break (flooding and/or washouts), close the valves and isolate the section as soon as possible, even before notifying all consumers.

After the valves are closed, a trash pump can be used to drain the hole. A backhoe or other equipment can be used to dig down to the break. Before entering the hole, determine the necessary shoring needed. Use the appropriate shoring. Remove the damaged section of pipe and as much silt and debris as possible from the remaining sections of the main by flushing or other methods. Replace the damaged section of pipe and/or valves using clamps and other fittings. Flush the entire section which was isolated using hydrants or drains. Disinfect the system by following the recommended standards for disinfecting mains.

All new or repaired watermains should be disinfected according to the current edition of the AWWA Standard for Disinfecting Water Mains Standard C651-92. New lines shall be thoroughly flushed and chlorinated at a dosage of 50 mg/L for 12 hours. In short lines, and if portable chlorination equipment is not available, thorough flushing and maintenance of a free chlorine residual of 1.0 mg/L after 24 hours shall be carried out, with a test for residual chlorine being made at the end of the test period.

Appendix K: Processes for Detecting Leaks

Leaks may originate from any weakened joint or fitting connection or from a damaged or corroded part of the pipe. Leaks are undesirable not only because they waste water, but because they can undermine pavements and other structures. Another undesirable effect of leaks is that the leak soaks the ground surrounding the pipe and in the event that pressure is lost in the pipe, the water, combined now with dirt and other contaminants, may backflow into the pipe.

The total amount of leakage is also affected by the type of soil surrounding the leaking pipes. In coarse soils (sands) the leakage may continue for an extended period without detection, whereas in finer soils (clays) leaks are detected sooner on the surface.

The process of locating a leak can be difficult and can become a troublesome and frustrating experience. Methods used to locate leaks include direct observation as well as use of sounding rods, listening devices, and data from a waste control study.

The simplest method of leak detection is to search for and locate wet spots which might indicate the presence of a leak. Sometimes these are reported by the system's customers. However, even if a damp spot is found, it does not necessarily mean the leak can be easily found. The leak may be located directly below the damp area or it may be metres away. Often the leak is not located where it would be expected because water follows the path of least resistance to the ground surface.

After the general location of the leak has been determined, a probe may be used to find the exact location. This probe is a sharp-pointed metal rod that is thrust into the ground and pulled up for inspection. If the rod is moist or muddy, the line of the leak is being followed. Do not probe into an area that has an electrical cable.

Listening devices are sound-intensifying equipment that is used in a systematic fashion to locate leaks. The simplest listening device is a steel bar held against the pipe or valve. The device is moved in the direction of increasing sound until the leak is found. Patented leak detectors use audiophones to pick up the sound of escaping water.

Another method for locating leaks is the use of a leak noise correlator. This instrument locates leaks by noise intensity and the time it takes for the leak sound to travel to a pair of microphones placed on fittings (fire hydrants or stop valves) on each side of a suspected leak. Leak correlators are fairly accurate in locating a leak.

The amount of water lost from the distribution system through leakage is only one component of the system's total water losses. The total amount of water lost from a distribution system from all sources is often referred to as "unaccounted for water" or non-revenue water (NRW). The NRW is the difference between the total amount of water produced and the total amount of water consumed. The amount of unaccounted for water lost by a distribution system is usually determined by conducting a water audit.

Waste control or water audit studies are usually conducted when no specific reason can be found for a significant water loss in the system. Routine comparisons of water production and use should be made to determine the amount of NRW or unaccounted for water. When the loss exceeds 10 percent of the water produced corrective actions should be taken.

Appendix L: List of Measurement Instruments, Alarms, Status Indicators, etc

Measurement Instruments

For plants of 1 ML/d (220,000 igpd) capacity and greater, the following instruments should be provided as a minimum for the relevant processes listed.

Raw Water Instrumentation

- Low-level switches to shut down the raw water pumps. These should be hard-wired to the starters.
- Running and trip indication for raw water pumps.
- Raw water turbidity, pH, pressure, flow rate, and flow volume.

Rapid Mixer

- Running and trip indication.

Flocculators

- Running and trip indication.
- Speed (if variable speed type).

Solids Contact Clarifiers

- Recirculator speed indication.
- Running and trip indication.
- Level indication.
- Blow down valve status.
- Turbidity and pH following clarification.

Softening

- If lime softening is used, pH following recarbonation.
- Recarbonation CO_2 feed status.

Filter Instrumentation

- Turbidity on each individual filter effluent and filter to waste. This can be a single instrument for each filter if piping arrangement permits.
- For constant rate filters: differential head loss across the filter media.
- Filter flow rate.
- Where the backwash sequence is automated, provide open and close limit switches or position on all filter valves and status on backwash equipment.
- Filter run time.

Backwash Instrumentation

- Running and trip indication for backwash pump(s).

- Running and trip indication for air blowers (if air scour is used).
- Backwash flow rate and flow total.
- Elapsed time since last backwash.

Clearwell and Distribution Pump Instrumentation

- Level indication for clearwell and other tanks.
- Running and trip indication for the distribution pumps.
- Low-level switches to shut down the distribution pumps. These should be hard-wired to the motor starters.
- Turbidity, chlorine residual, fluoride residual (if fluoridation is practised), pH, pressure, flow rate, and flow total on plant discharge.
- For variable speed pumps, indicate the pump speed.

Chemical Systems

- Running and trip indication for chemical loading, batching and pumping equipment.
- Low and high level alarms in storage bins, silos or tanks.
- Level indication for tanks.
- Weigh scales for hydrofluosilicic acid day tanks or storage if no day tank is used.
- Weigh scales for gaseous feed chemicals such as chlorine or sulphur dioxide.
- Speed indication on variable speed pumps.
- Rotameters (or other flow monitoring device) for carrier water feed systems.
- Chemical feed flow rate is desirable but not mandatory.

Miscellaneous Instrumentation

- Run time meters on all pumps and major electrically driven equipment.
- Speed, run time, oil pressure and temperature gauges, fault signal switches and manual start and shut down on engines.
- Where the plant is automated or operated remotely from either within the plant or outside, provide open and close limit switches or position indicators on all major valves, status on all major equipment and security instruments including door switches, building temperature switches and smoke alarms.
- Any additional instrumentation recommended by equipment manufacturers.

Alarms and Status Indication

As a minimum, the following alarms should be provided:

- High turbidity on the raw water, clarifier effluent (if applicable), filter effluent, and plant discharge.
- High and low pressure on the raw water line.
- High flow rate on the raw water line.
- High and low level in clarifiers or flocculators.
- High torque on solids contact clarifier recirculator and rake.
- High torque on flocculators.

- High level in filters.
- High and low level in chemical storage tanks.
- High and low chemical feed rates (if measurement is provided).
- High flow rate on each filter individually (also low flow rate on declining rate filters).
- High and low levels in each clearwell, pumpwell, and reservoir.
- High and low pH on the raw and treated water (if on-line measurements are provided).
- High and low chlorine residual on the plant discharge (where online measurements are provided).
- High head loss on the filters (if constant rate type).
- Trip or failure to run on each pump.
- High and low pressure on the plant discharge line.
- High flow rate on the plant discharge line.
- Chlorine gas detection in the chlorine storage rooms.
- Chlorine scale low weight (where scales are equipped with transmitters).
- Valve operation failure (where valves are provided with limit switches.

Field Instruments

<u>Level Instruments</u>

Where access to the top of the reservoir is convenient (such as in a clearwell), an ultrasonic level transmitter should be used. Where access to the bottom of the reservoir is convenient (such as at a tower or above-ground reservoir), a pressure transmitter can be used.

<u>Flow Instruments</u>

On-line flow meters should generally be one of the following types:

- Turbine (or nutating disk)
- Magnetic
- Ultrasonic (either transit-time or Doppler)

All of these types of instruments can be equipped to provide both flow rate and flow total measurements.

Price, line size, flow rate, flow range, pipe material, required accuracy, and water quality will dictate the selection of the type of instrument.

<u>Water Quality Instruments</u>

The most frequently used water quality measurements are turbidity, pH, and chlorine residual. On-line turbidity measurement is relatively inexpensive and should be provided in any plant, on the raw water, flocculator or clarifier effluent (if applicable), each filter effluent, and final plant discharge lines. In larger plants, on-line pH and chlorine residual are generally used, but manual testing can be done in smaller plants.

Process Controls

Pumping Systems

Regardless of the function of the pumping system, its control will normally be achieved through monitoring level, flow and/or pressure. The choice of control parameter(s) will depend on the system's function and features. Controls and monitoring for raw water pumping and finished water pumping are normally required.

Treatment Processes

Travelling Screens

Two methods may be used to control the operation of travelling screens:

- Simple manual start/stop which requires the presence of the operator to start and stop the screen. This method is not recommended where sudden changes in raw water quality could result in heavy debris accumulation on the screens.

- Automatic activation by differential level or time. This method uses the differential level across the screen to provide the start condition. Once started, the screen should run at least one "cycle" and stop automatically when the differential level is returned to the clean screen value.

Chemical Feed Systems

Liquid/Gas Chemical Feed

Basic chemical dose rate control can be achieved by flow pacing (i.e., adjusting chemical feed rate based on the flow of the stream it is to be injected into). This can be achieved using a variable speed metering pump (liquid) or flow control valve (gas) linked to a flowmeter on the receiving stream. For finer dosage adjustment, feed rate can also be controlled based on downstream instrumentation (e.g., residual chlorine analyzer providing feedback signal to chlorine dosing pump).

Dry Chemical Feed

Dry chemical feed systems typically include a packaged bulk storage combination feeder and mixer. The feeder can be gravimetric or volumetric, and will be controlled by a 4-20 mA signal from the flow transmitter on the plant flowmeter.

Rapid Mixing

Control of the rapid mixer will be simply on or off; the unit should operate continuously whenever the plant is in operation.

Flocculation

Flocculation requirements should be addressed in terms of the unit process parameters.

Clarification

Careful monitoring and control is most important to successful clarification. Adequate instrumentation to measure water quality parameters (e.g., turbidity) prior to and after clarification is essential.

Dissolved Air Flotation (DAF)

The process variables in DAF are:

- Flowrate
- Recycle rate
- Float removal cycle

Filtration

Two types of filtration are used for water treatment:

- Rapid gravity filtration.
- Slow sand filtration.

Rapid Gravity Filtration (RGF)

Constant Rate - Flow through a constant rate RGF is controlled by a flow control valve on the filter effluent or by influent flow splitting and filter level control. For the flow control type, the effluent valve position is controlled by a flowrate signal from a flow meter, usually located on the filter effluent. For the level control type, the effluent valve position is controlled by the water level in the filter.

A filter run will be terminated, and the bed backwashed, based on one or any of the following:

- Run time.
- Headloss across the bed.
- Effluent turbidity.
- Effluent particle count (optional).

Declining Rate - Flow through a declining rate RGF is not directly controlled as is the case with constant rate RGF. The rate simply decreases as the filter plugs. An effluent valve with manually adjustable stops is set to ensure the flowrate through a clean bed is not excessive. Once set, this valve will return to the set position after backwash (or after being closed for maintenance, etc.).

A filter run will be terminated based on one or any of the following:

- Run time.
- Effluent flowrate.
- Effluent turbidity.
- Effluent particle count (optional).

A time initiated backwash can be automatic. Smaller plants feeding smaller systems may benefit from backwashing overnight when demand is low - and the operator is not present. In such cases, a timer can be hard-wired into the filter control panel to initiate the backwash, or alternatively, the time control can be programmed into the plant's programmable logic controller (PLC).

Slow Sand Filtration
Because of the very slow flow rate through SSF, headloss, flow rate, and effluent quality can remain very stable for many weeks. Adjustments to the flow rate can be made manually by the operator.

Instrumentation should be provided to routinely monitor raw and treated water quality. A sudden increase in headloss accompanied by a reduction in flow rate signals that the filter is plugged.

<u>Disinfection</u>
The dosage is controlled on the basis of the measured residual; an analyzer/ controller measures the residual downstream of the point of injection and adjusts the rate of injection accordingly via a control signal to the metering pump (liquid feed) or gas flow control valve (gas feed).

Control System Documentation
The following documents should be provided following completion of the control system:

- Record drawings to show any changes to the original design and including any drawings produced during construction.
- Annotated listings of control system programs and packaged system configuration.
- Manufacturer's literature for all control and instrumentation components.
- Final wiring diagrams complete with wire and terminal coding.
- Motor control schematics.
- Instrument loop diagrams.
- Panel wiring and layout details.
- PLC or DCS wiring schematics.
- Instrument calibration sheets.
- Operating instructions.

Appendix M: Facility Classifications

Most jurisdictions in Canada classify water and wastewater facilities based on a point rating classification system developed by the Association of Boards of Certification (ABC), Ames, Iowa. Examples of the rating system are shown below.

Facility Classification System for Class I to IV

Type of Works	**Classification**	**I**	**II**	**III**	**IV**
WT	Range of points[a]	< =30	31-55	56-75	>=76
WD*	Population served	<=1500	1,501 -15,000	15,00	>=50,001 -50,000
WWT	Range of points	<=30	31-55	56-75	>=76
WWC*	Population served	<=1500	1,501 -15,000	15,001	>=50,001 -50,000

* Simple in-line treatment (booster pumping, chlorination or odour control) is considered to be a part of a distribution or collection system.

Notes:
WW - Waterworks
WWW - Wastewater works
WT - Water Treatment Facility
WD - Water Distribution Facility
WWT - Wastewater Treatment Facility
WWC - Wastewater Collection Facility

Appendix N: Operator Certification

Day-to-day operations of waterworks systems should be supervised by one or more persons who hold a valid certification for the type and class of facility concerned. This or these persons should be fully responsible for operation and maintenance of the facility. Typically, the approval for each facility should state the required number of certified operators and their required level of certification. The level of operator certification is to match or exceed the classification of the water treatment/distribution facilities. Various certification criteria have been developed through Canada based on ABC model. These criteria are shown below.

Summary of Operator Certification Criteria

Certification Class	Years of Education	Facility Experience	Other
Small System	10	6 months in a Small System or higher facility	Complete a small system
Level I	12	1 year in a Class I or higher facility	Complete a Level I certification exam
Level II	12	3 years in a Class I or higher facility	Complete a Level II certification exam
Level III	14	4 years in a Class II or higher facility	WT and WWT certificates require 2 yrs of DRC at Class II or higher facility.
Level IV	16	4 years in a Class III or Class IV facility	WT and WWT certificates require 2 yrs of DRC at Class III or Class IV facility. Complete a Level IV certification exam

Appendix O: Auditing Processes

Auditing can be done for a number of processes common to drinking water programs, including treatment systems, filtration systems, distribution systems and administrative systems. Below are some of the questions that may be asked during such audits.

Treatment System Audit

Suggested features and points of the water disinfection process to review are:

- Is the disinfection equipment and disinfectant appropriate for the application?
- Are there back-up disinfection units on line in case of failure, and are they operational?
- Is there auxiliary power with automatic start-up in case of power outage? Is it tested and operated on a regular basis, both with and without load?
- Is there an adequate quantity of disinfectant on hand and is it properly stored (e.g., are chlorine cylinders properly labelled and chained)?
- What is the production and expiry date on sodium and calcium hypochlorite containers?
- In the case of gaseous chlorine, is there automatic switch over equipment when cylinders expire?
- Are critical spare parts on hand to repair disinfection equipment?
- Is disinfectant feed proportional to water flow?
- Are daily records kept of disinfectant residual near the first customer from which to calculate CTs?
- Are production records kept from which to determine CTs?
- Is a disinfectant residual maintained in the distribution system, and are records kept of daily measurements?
- If gas chlorine is used, are adequate safety precautions being followed. Is the system adequate to ensure the safety of both the public and the employees in the event of a chlorine leak?

- Are other treatment processes appropriate and are they operated to produce consistently high water quality?

- Are pumps, chemical feeders, and other mechanical equipment in good condition and properly maintained?

- Are controls and instrumentation adequate for the process, operational, well maintained and calibrated?

- Are accurate records maintained (volume of water treated, amount of chemical used, etc.)?

- Are adequate supplies of chemical on hand and properly stored?

- Are adequate safety devices available and precautions observed?

Filtration System Audit

The type of treatment processes and facilities used to provide safe drinking water are determined by the type and quality of the source water plus regulatory requirements. In general, most surface water sources and some GWUDI require complete conventional treatment which includes coagulation/flocculation, sedimentation/clarification, and filtration processes to physically remove pathogens and other particulates, and disinfection to inactivate any pathogens that are not physically removed. The physical facilities at a conventional surface water treatment plant normally include chemical feed equipment, rapid mixing basins, flocculation basins, sedimentation/clarification basins, filters, and treated water storage facilities.

An auditor should evaluate all water treatment processes in use at the water system. This evaluation should consider the design, operation, maintenance, and management of the water treatment plant to identify existing or potential risks. The treatment and processes should be evaluated to assess the ability to meet intended purpose regulatory requirements at all times. An audit of a treatment plant should:

- Analyze all the parts of the treatment process, including but not limited to coagulation/flocculation, sedimentation, filtration, disinfection, chemical feed systems, hydraulics, controls, and wastewater management.

- Review source water quality data that may impact the treatment process, such as turbidity, pH, alkalinity, and water temperature.

- Identify features that may pose a risk, such as cross connections in the plant.

- Review the criteria, procedures, and documentation used to comply with regulatory requirements, for example, adequate disinfection based on CT values, individual filter turbidities, finished turbidities, post backwash turbidity profiles, etc.

- Is the treatment plant located at a level below the 100-year flood line?

- Are there any sources of contamination in the vicinity of the treatment plant which affect the quality of water produced?

- Do the plant drawing(s) shows the name of the facility and date of the last modification made to the drawing(s)? Are the drawings up-to-date?

- Are the schematic or layout plans complete with the proper information (e.g., a legend that explains key symbols used)?

- Do the schematics or plan(s) identify treatment type(s)?

- What is the design capacity of the treatment facilities? What is the historical maximum daily demand of the water system? What is the storage capacity of the system? Given service connections or population, are treatment facilities reasonable?

- Does the system meet regulatory requirements?

- Is the plant capable of meeting the required capacity with the largest unit out of service?

- What backup or standby provisions are available? If a generator is provided for emergency power, how often is the generator used? Can the operator demonstrate that the backup systems are operational?

- What protective storage measures are in place for fuel used in the standby generators?

- Can the operating characteristics of the existing units be checked? If so, does the purveyor check them periodically? How does the existing operational point compare to the original operational characteristics of the unit?

- Is the total capacity of the presedimentation basins large enough to accomplish the purpose of reducing turbidity?

- Check the turbidity levels of water drawn from the inlet and the outlet of the presettlement basin(s) to determine if it is functioning properly.

- How often are the presedimentation basins cleaned?

- Are flow measurement devices installed at source water inlet and finished water outlet? Are they functioning? Are they calibrated to assure accuracy?

- Are there adequate flow measurement devices throughout the treatment process?

- Does the rapid mix unit visually appear adequate?

- The auditor should look at the general sanitary condition of the housing of the rapid mix unit. Mouldy, dusty, and dirty walls and floors are signs of unsanitary conditions. The auditor should note the existence of wildlife taking shelter inside and even outside the housing unit and should note if there is a possibility that a wild animal or its feathers, fur, or droppings may end up inside the rapid mixing unit.

- Are coagulant chemicals being fed continuously during treatment plant operations?

- Does the plant have multiple mix units? How often is maintenance done?

- Is the mechanical equipment working and maintained? Are there any hydraulic inadequacies?

- Is the rate of mixing adjustable, so that the correct mixing can be provided at all flows? If so, can the operator adjust the rate of mixing?

- What is the detention time? Is it within the generally accepted range?

- What chemicals are used? Are the chemicals approved for use in drinking water? (e.g., NSF60)

- What chemical amounts are used - average and maximum? Are the various systems sized to feed more than the maximum amount required?

- Where are various chemicals applied?

- What type of chemical feed equipment is used? Are the materials used for each chemical feed system compatible with the chemical? What is the general condition of the chemical feed equipment?

- How often is the feed rate checked for each chemical?

- Is the control of the chemical feed equipment manual or automatic?

- Is a standby feeder and/or metering pump provided for each chemical?
- Is backflow prevention provided on the water lines used for chemical feed makeup?
- Is the storage area for each chemical adequate and safe? Is containment provided for a potential spill?
- What type of flocculation facilities are being used? Does the coagulation/flocculation process visually appear adequate?
- Does a preventive maintenance program exist?
- Is the rate of mixing adjustable, so that the correct mixing can be provided at all flows? If so, can the operator adjust the rate of mixing?
- What type of sedimentation/clarification process and facilities are being used? Does the sedimentation/clarification process visually appear adequate?
- Is the flow distributed evenly to all basins? Is the inlet flow distributed uniformly over the full cross section?
- Is the mechanical equipment working and maintained? Are there any hydraulic inadequacies?
- Does there appear to be too much sludge in the basin(s)? How is sludge removed from the clarifier(s)? How often is sludge removed?
- What is the settled water turbidity? Does it meet the general criteria?
- What type of filtration system is being used (gravity or pressure; constant or declining rate) and what kind of media has been installed (mono media, dual media, or multi media)?
- What is the maximum filtration rate at design capacity with one filter out of service? Is it at or less than the maximum water demand?

If a pressure filtration system is installed, then the following should be checked:

- When was the last internal inspection of the filters performed? Is the inspection frequency in accordance with regulatory requirements?
- What is the turbidity of the backwash waste?

- What is the turbidity level of the effluent water following the backwash?

- Does the first forward flow go to waste?

If a gravity filtration system is installed, then the following should be checked:

- Is there any visible indication of problems on the surface of the filter?

- Are there any pressure relief vents from the underdrain through the filter media?

- Is the monitoring instrumentation (loss-of-head, effluent flow rate, and filtered water turbidity) working for all filters? What condition is the instrumentation in?

- What criteria are used by operators to determine when a filter requires backwashing? Are filters ever stopped, then started-up again without backwashing them first? Are filters ever "bumped" to extend filter runs?

- Is there a means of measuring the backwash flow rate? What is its condition? When was the flowmeter calibrated last? Can the backwash flow be varied to allow for varying conditions?

- Are newly backwashed filters brought back into service at low rates that are gradually increased (ramped-up) in order to minimize post-backwash turbidity spikes? Are operating filter flow rates reduced when another filter is backwashed?

- What is the condition of the piping in the filter gallery? Is it colour coded for the use or service in accordance with regulatory requirements? Are there any cross-connections?

- Is there a floor drain to remove all leaking water from the filter gallery floor?

- What type of disinfection process and facilities are used at the treatment plant? Does the operator understand the disinfection process?

- What is the chlorine residual leaving the treatment plant? Do disinfectant residuals meet regulatory requirements?

- How are wastewater from the backwash process and sludge from the sedimentation process managed?

- Does the water system have a cross connection control plan for the plant? Is the program active and effective in controlling cross connections?

- What are the water uses in the plant? Where does the supply for these uses come from? Are proper backflow prevention devices installed to protect potable water at the plant?

- Are the appropriate backflow preventers used for all existing cross connections? The auditor should have a copy of CAN/CSA B64.10 Manual for the Selection, Installation, Maintenance, and Field Testing of Backflow Prevention Devices.

Audit Priority Criteria

The following criteria related to the water treatment element of the audit are considered high priority based on their potential for impacting public health:

- Capacity of Treatment Facilities
- Rapid Mix, Chemicals and Chemical Feed Systems, and Coagulation/ Flocculation
- Sedimentation/Clarification
- Filtration
- Disinfection
- Waste Streams
- In-Plant Cross-Connection Control
- Treatment Plant Schematic/Layout Map

Distribution System Audit

After water has been treated, water quality must be protected and maintained as it flows through the distribution system to the customer's tap. The following questions relate to the water purveyor's ability to maintain high water quality during storage and distribution.

Storage

Gravity

- Are storage reservoirs covered and otherwise constructed to prevent contamination?

- Are all overflow lines, vents, drainlines, or cleanout pipes turned downward and screened?

- Are all reservoirs inspected regularly?

- Is the storage capacity adequate for the system?

- Does the reservoir (or reservoirs) provide sufficient pressure throughout the system?

- Are surface coatings within the reservoir in good repair and meet National Sanitation Foundation (NSF) Standard 6.1.
- Is the hatchcover for the tank watertight and locked?
- Can the reservoir be isolated from the system?
- Is adequate safety equipment (caged ladder, approved safety belts, etc.) in place for climbing the tank?
- Is the site fenced, locked, or otherwise protected against vandalism?
- Is the storage reservoir disinfected after repairs are made? What disinfection process standard is followed?
- Is there a scheduled program for cleaning storage reservoir sediments, slime on floor and side walls.

Hydropneumatic

- Is the storage capacity adequate for the system?
- Are instruments, controls, and equipment adequate, operational, and maintained?
- Are the interior and exterior surfaces of the pressure tank in good condition?
- Are tank supports structurally sound?
- Does the low pressure cut in provide adequate pressure throughout the entire system?
- Is the pump cycle rate acceptable (not more than 15 cycles/hour)?

Cross Connections

- Does the utility have a cross connection prevention program, including annual testing of backflow prevention devices?
- Are backflow prevention devices installed at all appropriate locations (wastewater treatment plant, industrial locations, hospitals, etc.)?
- Are proper pressures and flows maintained at all times of the year?
- Do all construction materials meet AWWA, NSF or equivalent standards?
- Are all services metered and are meters read?
- Are plans for the system available and current?
- Does the system have an adequate maintenance program?

- Is there evidence of leakage in the system?
- Is there a pressure testing program?
- Is there a regular flushing program?
- Are AWWA standards for disinfection followed after all repairs?
- Are there specific bacteriological criteria and limits prescribed for new line acceptance or following line repairs?
- Describe the corrosion control program.

Administrative Audit

- Is there an organization that is responsible for providing the operation, maintenance, and management of the water system?
- Does the utility regularly summarize both current and long-term problems identified in their watershed, or other parts of the system, and define how they intend to solve the problems, i.e., is their planning mechanism effective; do they follow through with plans?
- Are customers charged user fees and are collections satisfactory?
- Are there sufficient personnel to operate and manage the system?
- Are personnel (including management) adequately trained, educated, and/or certified?
- Are operation and maintenance manuals and manufacturers technical specifications readily available for the system?
- Are routine preventative maintenance schedules established and adhered to for all components of the water system?
- Are sufficient tools, supplies, and maintenance parts on hand?
- Are sufficient operation and maintenance records kept and readily available?
- Is an emergency plan available and usable, and are employees aware of it?
- Are all facilities free from obvious safety defects?

When the survey is completed, it is preferable to briefly summarize the survey with the operator(s) and management. The main findings of the survey should be reviewed so it is clear that there are no misunderstandings about the findings.

Acronyms

AFR	Arbitrary fixed radius
AMO/MEA/OGRA	Association of Municipalities of Ontario, Municipal Engineers Association and the Ontario Good Roads Association
AVI	Aquatic Vulnerability Index
AWWA	American Water Works Association
CCME	Canadian Council of Ministers of the Environment
CCPs	Critical Control Points
CDW	Federal-Provincial-Territorial Committee on Drinking Water which reports to the Federal-Provincial-Territorial Committee on Health and Environment
CFR	Calculated fixed radius
CT	Contact Time (of disinfectant in water)
CTIC	Conservation Technology Information Center
CWWA	Canadian Water and Wastewater Association
DBPs	Disinfection By-Products
DSS	Decision support systems
EQGs	Environmental Quality Guidelines
EQOs	Environmental Quality Objectives
FCA	Full-cost accounting
FCM	Federation of Canadian Municipalities
GIS	Geographic Information System
HACCP	Hazard Analysis and Critical Control Points
MAPAQ	Ministry of Agriculture, Fisheries and Food of Quebec

MF	Microfiltration (drinking water treatment process)
MPA	Microscopic particulate analysis
NF	Nanofiltration (drinking water treatment process)
NRC	Natural Resources Canada
OMAFRA	Ontario Ministry of Agriculture, Food and Rural Affairs
PPCPs	Pharmaceuticals and Personal Care Products
RO	Reverse osmosis (drinking water treatment process)
SCADA	Supervisory control and data acquisition equipment
SSO	Site specific objective
SWP	Source water protection
TDML	Total maximum daily load
TDS	Total Dissolved Solids
TOT	Time of Travel (for streamflows)
TQM	Total Quality Management
UF	Ultrafiltration (drinking water treatment process)
US EPA	United Stated Environmental Protection Agency
WHMIS	Workplace Hazardous Materials Information System
WHO	World Health Organization
WQTG	Water Quality Task Group of the Canadian Council of Ministers of the Environment

Glossary

Acute Health Effect An immediate (within hours or days) effect that may result from exposure to certain drinking water contaminants.

Anthropogenic Resulting from the influence of humans; induced or altered by human presence or activities.

Aquifer Geological formation of permeable rock, sand, or gravel that conducts ground water and yields significant quantities of water to springs and wells.

Aquitard Geological formation of a semi-impermeable and semi-confining nature, which transmits water at a very slow rate. It serves mostly as a storage unit for groundwater rather than yield water to springs or wells.

Artesian Well A well in which water from a confined aquifer rises above the water table of the aquifer.

Bacteria Simple, unicellular organisms with an average size of 1/1,000 mm diameter.

By-product New products or substances formed when a chemical reaction occurs.

Catchment A surface from which draining water is collected.

Chloramines Chemical compounds of chlorine and nitrogen used in disinfection of drinking water.

Chronic Health Effect The possible result of exposure over many years to a drinking water contaminant.

Cistern A water storage tank typically used for catching and storing rainwater.

Coliform Bacteria A group of related bacteria whose presence in drinking water may indicate contamination by disease-causing microorganisms.

Conductivity The property of a body to conduct electricity.

Contaminant Anything found in water that might be harmful to human health.

Cryptosporidiosis — The illness caused by *Cryptosporidium*.

Cryptosporidium — A protozoa commonly found in lakes and rivers, which is highly resistant to disinfection. May cause gastrointestinal illness.

Disinfection — A chemical or physical process that kills microorganisms.

Disinfection by-products — Chemical compounds that result from the reaction of disinfectants with organic matter in the water being treated.

Erosion — Process whereby the materials of the Earth's crust are loosened, dissolved, or worn away. Erosion results in higher sedimentation of particles in bottom of in water plans.

Eutrophic — Designating a water plan enriched in dissolved nutrients that stimulate the growth of aquatic plant life and usually resulting in the depletion of dissolved oxygen.

Exposure — Accessibility to drinking water contaminants that may cause harm or danger to the consumer.

Finished Water — Water that has been treated and is ready to be delivered to consumers.

Giardia — A protozoa frequently found in rivers and lakes, which, if not treated properly, may cause gastrointestinal illness.

Groundwater — The water found in underground aquifers which supplies wells and springs.

Hazard — A source of danger or harm to the drinking water consumer.

Hydraulic — Operated, moved, or effected by a fluid under pressure, often water.

Hydrology — Science studying properties, distribution, and effects of water on the Earth's surface.

Local Authority — The group or organization that has the local control over the drinking water supply, such as a municipality or conservation authority.

Irrigation — The artificial supply and application of water to the soil to maintain moisture in crop fields.

Microorganisms	Living organisms that can be seen only with the aid of a microscope.
NTU	Nephelometric Turbidity Unit – a unit that expresses the amount of turbidity in water.
Oligotrophic	Designating a water plan with a low nutrient content. As a result, algal growth is minimal.
Owner/operator	The organization or person(s) who own or run the drinking water system (including treatment plant(s) and distribution system). Examples include public or private water utilities.
Pathogen	A disease-causing organism.
Porosity	Property of a solid containing minute channels or open spaces, often referred as the ratio of the volume of all the pores in the solid to the volume of the whole.
Private Water System	Individual domestic drinking water system used for personal or family needs only.
Protozoa	Single-celled organisms. More complex physiology than viruses and bacteria. Average size of 1/100 mm diameter.
Raw Water	Water in its natural state, prior to any treatment for drinking.
Riparian	Of or on a riverbank.
Risk	The possibility of suffering, harm, or danger from consuming drinking water.
Sanitary Survey	An on-site assessment of the water sources, treatment facilities, equipment, operation, and maintenance of a water system for the purpose of evaluating the adequacy of the facilities for producing and distributing safe drinking water.
Sedimentation	The process of settling and deposition of suspended matter in the bottom of a water plan.
Semi-Public Water System	Drinking water system with fewer source connections than regulated for a public system but more than for personal or family use.

Source Water	Water in its natural or raw state, prior to being withdrawn for treatment and distribution as a drinking water supply.
Stakeholder	Person or group of people affected by, or who can influence, a decision or action.
Surface Water	The water from sources open to the atmosphere, such as rivers, lakes, and reservoirs.
Topography	Three-dimensional graphic representation of the elevations or inequalities of the Earth's surface.
Total Organic Carbon	A laboratory measurement that indicates the amount of organic matter in water.
Transmissivity	A measure of the rate of movement of water through an aquifer.
Turbidity	The cloudy appearance of water caused by the presence of tiny organic or inorganic particles.
Vadose	Relating to an area with dry and wet periods depending on groundwater table level.
Virus	Very simple life forms that do not multiply outside of living host cells. Average size of 1/10,000 mm diameter.
Velocity	Rate of movement of an object past a point in a specified direction.
Watershed	The area draining naturally from a system of watercourses and leading to one body of water.
Wellhead	The structure built over a well to maintain water protection. The land area surrounding a drinking water well or well field.

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