Standards and Guidelines for Municipal Waterworks, Wastewater and Storm Drainage Systems

Part 2
Guidelines for Municipal Waterworks
of a Total of 5 Parts

April 2012

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Part 2 GUIDELINES FOR MUNICIPAL WATERWORKS

April 2012

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FOREWORD TO PART 2 GUIDELINES FOR MUNICIPAL WATERWORKS (2012)

Alberta Environment and Sustainable Resource Development (AESRD) is responsible for the Drinking Water and Wastewater Programs for large public systems in Alberta. AESRD considers the establishment of standards and guidelines for municipal waterworks, wastewater and storm drainage facilities an integral part of our regulatory program directed at ensuring public health and environmental protection. AESRD's objective is to develop comprehensive and scientifically defensible standards and guidelines that are effective, reliable, achievable and economically affordable.

Since publication of the last revision of the Standards and Guidelines, Alberta Environment and Sustainable Resource Development has embarked on a process of "decoupling" the various components of the January 2006 document into functionally-associated sections to aid those using the document. This process started with the publication of the January 2006 version of the Standards and Guidelines for Municipal Waterworks, Wastewater and Storm Drainage Systems in the Alberta Gazette. A program of separating the component parts of this document is under way and new parts will eventually replace the corresponding sections in the January 2006 Standards and Guidelines for Municipal Waterworks, Wastewater and Storm Drainage Systems. Until the process of "decoupling" is completed with new "Parts" the existing sections of the 2006 Standards and Guidelines document will remain in operation. This Part (Part 2) details system components that are guidance to best practices in providing safe drinking water and should be read in conjunction with Part 1 – Standards for Municipal Waterworks (2012).

Alberta Health Services is responsible for the application of the Public Health Act of Alberta. The role of Alberta Health Services, in the spirit of the Public Health Act, applies to all drinking water systems, both large and small, and to all aspects of safe drinking water production and delivery, if there is a concern about health impacts or disease transmission.

The system owners / utilities are responsible for meeting AESRD's regulatory requirements and for the production and delivery of safe drinking water to the consumers. They are also responsible for maintaining water distribution system to the service connection, and will assist the home / building owners to identify any water quality issues within building plumbing. However, home / building owners are still responsible for plumbing repairs, system corrections and water quality within their building.

Engineering consultants and / or the system owners / utilities are responsible for the detailed project design and satisfactory construction and operation of the waterworks and wastewater systems.

In accordance with the Potable Water Regulation (277/2003) a waterworks system will be designed so that it meets, as a minimum, the performance standards and design requirements set out in the Standards and Guidelines for Municipal Waterworks, Wastewater and Storm Drainage Systems, published by AESRD, as amended or replaced from time to time, or, any other standards and design requirements specified by the Regional Director. AESRD last revised its Standards and Guidelines for Municipal Waterworks, Wastewater and Storm Drainage Systems in January 2006.

This present part is intended to provide general guidance on how to achieve a certain level of system performance or reliability. Good engineering and best management practices are included in this Part. These are not mandatory requirements but they establish the minimum quality of the facility expected when the system owner/ utility applies for an approval.

In this version of Part 2 – Guidelines for Municipal Waterworks the only changes from the January 2006 version of the Standards and Guidelines for Municipal Waterworks, Wastewater and Storm Drainage Systems are in the listing of the Appendices. The 2006 Appendix D is now located in Part 1 – Standards for Municipal Waterworks as Appendix 1-D; Appendix F from the 2006 document is now in this present part as Appendix 2-A. There is no change to the content of the Appendices.

DEFINITIONS / ABBREVIATIONS

AO	-	Aesthetic Objectives
AESRD	-	Alberta Environment and Sustainable Resource Development
AWWA	-	American Water Works Association
BDOC	-	Biodegradable Dissolved Organic Carbon
BNR	-	Biological Nutrient Removal
BPJ	-	Best Professional Judgement
BPR	-	Biological Phosphorus Removal
BPT	-	Best Practicable Technology
CBOD	-	Carbonaceous Biochemical Oxygen Demand at 5 days and 20 ^oC
CFID	-	Continuous feed and intermittent discharge
DAF	-	Dissolved Air Flotation
DBP	-	Disinfection By-product
DCS	-	Distributed Control System
DO	-	Dissolved Oxygen
DOC	-	Dissolved Organic Carbon
DWSP	-	Drinking Water Safety Plan
EPEA	-	Environmental Protection and Enhancement Act
F/M	-	Food to Microorganism ratio
G	-	Velocity Gradient
GCDWQ	-	Guidelines for Canadian Drinking Water Quality
GWUDI	-	Groundwater under the direct influence of surface water
HPC	-	Heterotrophic Plate Count
HRT	-	Hydraulic Retention Time
IFID	-	Intermittent feed and intermittent discharge
MAC	-	Maximum Acceptable Concentration
MLSS	-	Mixed Liquor Suspended Solids
NH_3-N	-	Ammonia nitrogen
NSF	-	National Sanitation Foundation
NTU	-	Nephelometric Turbidity Unit
ORP	-	Oxidation Reduction Potential
OU	-	Odour Unit
PLC	-	Programmable Logic Controllers
QA/QC	-	Quality Assurance/Quality Control
RBC	-	Rotating Biological Contactor
SAR	-	Sodium Adsorption Ratio
SBR	-	Sequencing Batch Reactor
SRT	-	Sludge Retention Time
TBOD	-	Total Biochemical Oxygen Demand at 5 days and 20 ^oC
TOC	-	Total Organic Carbon
TP	-	Total Phosphorus
TSS	-	Total Suspended Solids
TTHM	-	Total Trihalomethanes
UC	-	Uniformity Coefficient
USEPA	-	United States Environmental Protection Agency
UV	-	Ultraviolet
WHO	-	World Health Organization

Average daily design flow - The product of the following:

- design population of the facility, and
- the greatest annual average per capita daily flow which is estimated to occur during the design life of the facility.

Co-op - An organization formed by the individual lot owners served by a waterworks system, wastewater system or storm drainage system.

Granular Filter Media:

1. Effective Size (D_{10}) - Size of opening that will just pass 10% of representative sample of the granular filter media.
2. Uniformity Coefficient - A ratio of the size opening that will just pass 60% of the sample divided by the opening that will just pass 10% of the sample.

Groundwater - All water under the surface of the ground.

Maximum daily design flow (water) - Maximum three consecutive day average of past-recorded flows, times the design population of the facility. If past records are not available, then 1.8 to 2.0 times the average daily design flow.

Maximum hourly design flow (water) - 2.0 to 5.0 times the maximum daily design flow depending on the design population.

Owners - Owners of the waterworks systems as defined in the regulations.

Peak demand design flow (water) - the maximum daily design flow plus the fire flow.

Potable Water – As defined in the EPEA. Other domestic purposes in the EPEA definition include water used for personal hygiene, e.g. bathing, showering, washing, etc.

Sodium Adsorption Ratio - A ratio of available sodium, calcium and magnesium in the soil solution which can be used to indicate whether or not the accumulation of sodium in the soil exchange complex will lead to a degradation of soil structure.

$$SAR = \frac{Na}{[\frac{Ca}{2} + \frac{Mg}{2}]^{1}/^{2}}$$

Note : All concentrations expressed in milliequivalents per litre

Surface water - Water in a watercourse.

Watercourse - As defined in the EPEA.

2.0 Waterworks Systems Guidelines

2.1 Design Criteria

2.1.1 Water Quantity Requirements

A general correlation exists between the available quantity of drinking water and the level of public health within a community. The waterworks system shall be capable of providing sufficient quantities of water to meet the needs of consumers, meaning that the proposed source of supply should adequately meet the demand of consumers without any adverse effects on other water users. Water quantity requirements should be based on an assessment of all existing and possible future domestic, institutional, commercial and industrial demands, and should also consider possible water demands for fire fighting purposes.

Water is also a natural resource, which should be managed and used in a responsible manner. Water conservation measures that eliminate water misuse or wastage should be implemented; water metering is a particularly effective method of encouraging the responsible use of water. The use of water saving fixtures, upgrading or replacement of leaking water distribution piping, water use restrictions, and proper water treatment plant operation are other water saving measures which should be considered when determining water requirements.

2.1.2 System Capacity

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 for the entire design horizon which is at least 20 to 25 years. Storage facilities, on the other hand, should be phased to avoid operational problems (such as increased chlorine demand or oversized pumps) which are associated with excess storage and detention times.

2.1.3 Raw Water Supply and Water Treatment

The raw water supply and water treatment plant should be designed for at least 110% of the projected maximum daily design flow. This compensates for accumulated in-plant losses of up to 10% of the produced treated water.

2.1.4 Water Distribution

Water distribution system should be designed to handle a normal operating pressure between 350 kPa and 550 kPa under a condition of maximum hourly design flow. Distribution system pressures above 550 kPa should be reviewed against the Canadian Plumbing code to determine specific building/household requirements to avoid damage to internal building/household piping.

In order to provide adequate service, the minimum distribution pressure during peak demand design flow should be 150 kPa.

In addition to the maximum operating pressures, there are transient pressures due to pump starts and stops, power failures, or rapid valve operation. Pumps should be designed to minimize these surges, and water mains should be designed to withstand these surges, in addition to the maximum operating pressure.

At the discretion of municipalities, distribution mains may be located on lands controlled by the municipality.

2.2 Raw Water Supply

2.2.1 Source Water Protection

Source protection is used to control or minimize the potential for introduction of chemicals or contaminants in source waters, including water used as a source of drinking water. Since almost all water, both surface and groundwater may be a potential source; this really is about the protection of all water resources. Thus, source protection is really the equivalent of, or at least a component of a watershed management plan that usually focus on general (ambient) water quality. The focus in a comprehensive plan will be on contaminants that pose a threat to human health as well as aquatic life.

A waterworks utility needs to have a comprehensive, source-to-tap plan in order to ensure safe drinking water. A source protection plan is only one of the elements of a source-to-tap plan. The utility need not take on the source protection responsibility alone, and in fact, likely can't accomplish it without the involvement and cooperation of others. The source protection component may be achieved in conjunction with other efforts such as watershed management planning and this will serve to perform the first barrier in the multi-barriers in the source-to-tap approach. The watershed management planning process will quite likely involve a wide range of participants including, but not limited to, federal, provincial and municipal governments, watershed groups, stakeholders, and the public. The waterworks utility needs to be a participant in this process as a stakeholder.

In late 2003, the Government of Alberta released *Water for Life: Alberta's Strategy for Sustainability*. Alberta Environment and Sustainable Resource Development will lead this initiative but the strategy is based on a shift to shared governance through partnerships, including federal, several provincial ministries, municipal and non-government organizations. This strategy will form the framework for province-wide water management planning. The planning areas will be based on watershed scale planning areas. It is this process that waterworks utilities should be preparing to participate.

The goal of a successful plan is to provide guidance in making decisions, by anyone with the authority to do so, so that the outcome is consistent and coordinated. For example, a municipal development authority may use the plan to make decisions on land use. Another example is a provincial government authority making a decision regarding a point-source discharge. The plan communicates the desires, intentions, and possible consequences of decisions.

The waterworks utility's perspective and input into the process needs to be on contaminants that may not be adequately controlled by the treatment system of a waterworks system. Typically, a water treatment system is designed based on the quality of the source water at the time of initial construction or a major upgrade. In order for the treatment system to function well in producing an acceptable product water quality, the source water quality must remain within the anticipated range of quality.

If contaminants are introduced into the system for which the treatment system was never designed or intended to remove, the contaminant has the potential of passing through the process and being present in the finished water. Increased concentrations of contaminants for which the system was designed may result in breakthrough due to exceeding the design criteria. Contaminants that appear and will remain present in the source water after design and construction of the plant effectively reduce the design life of the system. This is a significant impact on the capital investment.

A reduction in contaminants in the source water may have the benefit of improving the finished water quality and potentially extending the design life of the facility thereby providing benefits over and above simply protecting the investment.

A source protection plan must identify the threshold within which the source water is of adequate quality. This is accomplished by reviewing the ability of the selected or existing technology to reduce or remove any given contaminant. Any additional contaminants or concentration of contaminants would therefore threaten the ability of the treatment system to produce adequate quality water.

The plan must examine the source for the existence, or potential for introduction of, contaminants that are above or outside the acceptable range. Once these contaminants are identified, the potential source of the contaminants can be determined and control measures implemented.

Control measures are not limited to eliminating the practice of the activity within the upstream watershed, but may include multiple levels of providing protection that will effectively eliminate the threat and provide satisfactory protection of the finished water quality.

2.2.1.1 Surface Water or Groundwater under Direct Influence of Surface Water Sources

Surface water sources are the most difficult to protect since they may be subject to both point source and non-point source contaminant introduction. The number and type of contaminants are as diverse as the number of activities that may occur in the watershed upstream of the intake. In addition, the travel time to an intake for any given contaminant is likely to be much shorter than for a groundwater source. This results in the area to be considered within the plan to be extended much further upstream to provide adequate detection and reaction time.

Most conventional surface water treatment systems are designed for removal of suspended sediments and organics such as parasites and microbes. These systems typically are not intended to remove dissolved substances although some incidental removal may be accomplished. The normal method of determining the efficiency of the physical treatment is log reduction of particles. Turbidity is used as an indirect measurement of the number of particles in water. Turbidity reduction to below a specified level is assumed to have achieved the required log reduction.

The initial pre-design water quality characterization must identify the level of log reduction required for the source water. If the value of this parameter in the source water is constant, the system should continue to perform adequately. However, if the parameter is not constant, and over time varies above the initial assessment value, the treatment system will effectively have its useful life shortened. An unplanned upgrade will be required to maintain the same level treatment as was originally anticipated for the life of the facility.

The presence and baseline concentrations for other chemicals such as pesticides should be evaluated. Although most of these contaminants are likely to be well below levels of concern, monitoring the trend over time will allow review of the adequacy of the protection plan in controlling these chemicals.

Source protection measures may include programs for:

- land use/buffer zones,
- agricultural tillage practices,
- stormwater management,
- material disposal and recycling,
- landfills,
- used oil collection,
- pesticide container collection,
- hazardous waste round up,
- private sewage systems siting, construction and management,
- shoreline and riparian area restoration,
- and many others.

2.2.1.2 Groundwater

Waterworks systems that are served by high quality groundwater sources are not immune to potential contamination and require source protection just like surface sources. The main difference is in identification of the potential points of entry of contaminants into the aquifer. For the most part, these will be point sources such as the wellhead itself, other wells that utilize the same aquifer as a source, or areas of high permeability and recharge. In addition, the delineation of the aquifer may be somewhat more difficult as the extent of the source is not as readily identified.

Each well provides a potential conduit for contaminants into the aquifer. Although control of many of these wells will not rest with the protected system's owner, an education program for private owners will certainly reduce the risk of accidental contamination. Simply knowing the number and types of wells, including their intended use, will provide the ability to identify hazards and prepare contingency plans.

Unused wells also present a hazard to the aquifer. The owners of the wells may be reluctant to permanently abandon (plug and seal) these wells, and wish to retain them as a back-up source. However, the reason for seeking an alternate supply was likely that the well was inadequate in meeting the demands or it suffered partial or complete failure.

Every well, including the protected system's well, whether or not the wells are used regularly or kept for backup, need to be properly sited, constructed, and protected. Wells must be sited on relatively high ground such that water will not pool around the casing. The well construction must ensure that the well is completed in a single aquifer to prevent cross-contamination. The annular space surrounding the casing must be sealed to prevent vertical movement along the casing. The top of the casing must extend above the ground to the highest recorded flood water level.

The presence and baseline concentrations for other dissolved chemicals should be evaluated. Although most of these contaminants are likely to be well below levels of concern, monitoring the trend over time will allow review of the adequacy of the protection plan in controlling these chemicals.

2.2.1.3 Summary

Source protection for waterworks utilities can be accomplished by preparing for, and participating in the *Water for Life; Alberta's Strategy for Sustainability* process. Waterworks owner's can prepare for this process by identifying potential partners, issues and concerns pertinent to their facility, and identifying potential solutions. Each utility will likely share concerns with other neighbouring facilities in the same area and can collaborate to share information and efforts.

Successful development and adoption of a source protection plan, even one that is shared with others, will be of great benefit to the overall source-to-tap protection system.

2.2.2 Water Source/Quality

Raw water from a selected source should be of sufficient quality such that it can be economically treated to produce finished water which complies with the potable water quality (Section 1.1) and the treatment requirements outlined in Section 1.2. Factors that influence the choice of the raw water source should include reliability, treatability, environmental impact, and economics. The choice of filtration process should be based on total coliform count, turbidity and TOC as presented in Table 2.1.

As the level of treatment required would be dependent on the raw water quality, the owners may develop watershed protection programs to reduce any potential risk of source pollution. The owners may maintain a sanitary control area around all sources for the purpose of protecting them from existing and potential sources of contamination. The owners may also develop a watershed control program, identifying land ownership and activities which may adversely affect source water quality and develop watershed control measures, including documentation of ownership and relevant written agreements and monitoring of activities and water quality.

2.2.3 Site Selection Criteria

Several factors that should be considered when selecting a site for new or expanded water supply and treatment works include:

1. isolation from non-compatible land uses;
2. facility location with respect to the raw water source, the area(s) being serviced, and proximity to associated utilities;
3. physical site problems including susceptibility to flooding, subsurface geology, or proximity to natural watershed areas; and
4. adequacy of the site for future expansion.

TABLE 2.1
Generalized Capabilities of Filtration / DAF Systems to Accommodate Raw Water Quality Conditions

Treatment	General Restrictions			
	Total Coliforms (#/100 mL)	**Turbidity (NTU)**	**TOC**	**Protozoa**
Conventional filtration	< 20,000***	No restrictions	No limit	< 3 log
Direct filtration**	< 500	< 7-14	< 3	< 2.5 log
Slow sand filtration	< 800	< 10	< 2	< 3 log
Membrane Filtration	N/A	< 100 NTU	< 2	Based on challenge test
DAF		< 100	No limit	N/A

* Shall insure control of disinfection by-products
** When TOC > 3 mg/L turbidity reduction is impaired
*** When total coliforms > 20,000/100 mL, or TOC > 10 mg/L, additional treatment may be required
Note: Ideally pilot testing should be conducted to demonstrate the efficacy of the treatment alternatives.

2.2.4 Surface Water Supply

2.2.4.1 Intakes

1. Sizing

For the reasons discussed under Section 2.1.2, intakes should be sized for an extended design period (as compared to a phased design), which is usually about 20 to 25 years.

2. Design

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. The designer should be familiar with the requirements as legislated under the Navigable Waters 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 in that 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.

River hydrology must be considered where the riverbed is subject to movement. Design the intake to minimize drawing in Frazil ice.

All intakes in fish bearing waters require Federal Department of Fisheries and Oceans approval.

An acceptable alternative design to direct intake is an infiltration gallery intake. This type of intake is suitable when the riverbed 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:

a. the sediment load in the river (may necessitate backwashing or aeration provisions);

b. the use of filter cloth; and

c. 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).

2.2.4.2 Screening

1. Sizing

   Screen mesh size should be governed by the surface raw water quality and the species of fish present in the raw water supply. Screen size requirements shall be in accordance with requirements of the provincial department of Fish and Wildlife or the federal Department of Fisheries and Oceans.

2. Location and Type of Screen

   Screens may be constructed either at the intake structure itself or in-plant just prior to the raw water pumping facilities. For small treatment plants with in-plant screens, two (2) fixed screens in series will suffice, while for larger plants the use of at least two (2) mechanically cleaned screens operating in parallel is recommended. A combination of fixed and mechanically cleaned screens may be used for medium capacity plants. Screens at the intake should comply with the requirements stipulated by the federal and provincial departments of Fish and Wildlife or the federal Department of Fisheries and Oceans.

3. Washing

   Fixed screens should have lifting lugs for removal and washing. Screen waste should not be returned to a raw water storage area.

2.2.4.3 Pumping

Pumps should be specified so that the full range of flows anticipated can be provided with pumps operating in the vicinity of their optimum efficiency points, with due regard 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 are 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 as stated in section 2.1.3.

Provision should be made for an individual pressure gauge on each pump and an isolating valve and check valve on the discharge side. Dry well pumps should be provided with suction side valves. The use of slow opening pump discharge should be considered at raw water pumping stations remote from the treatment plant. Piping should be arranged to allow ready disassembly from pump to shut off valves, and include a flexible type coupling to permit proper alignment of the piping and pump. Couplings shall be adequately protected against thrust. Pump elbows should be supported to remove all bending moments, either steady or shock, from pump nozzles.

The station design should allow for future additional pumping units and where possible, the pipe work 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 for removal of pumps, and 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 raw water well.

All piping should be arranged so that 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.

Pumps should be mounted on bases above the floor level, and all access openings into the well shall have suitable curbs around them to prevent floor drainage entering the well. The station floor should be sloped to floor drains. Floor drainage back to the raw water well is not permitted. Drainage from pumps on to the floor is not acceptable.

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. Where control valves accomplish this, it is normal practice to use butterfly valves operating in a range to maintain stable control and avoid cavitation. 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.

2.2.4.4 Raw Water Storage

Raw water storage improves water quality by providing presedimentation 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 raw water quality, allowing a low rate of withdrawal at the source.

1. Facility Planning

   The designer should assess the need, location, and sizing of the raw 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. The designer should also consider any potential adverse effects on the water intake, storage, or treatment facilities; and should include design features to minimize the effects of fluctuating raw water turbidity.

2. Multi-Cell Provision

Raw water reservoirs should be constructed with a minimum of two cells. This will enable the plant operator to withdraw raw water from the second cell when the first cell is being filled or repaired. Each cell should be sized to retain about 75% of the annual raw water needs. In areas of drought, the number and storage capacity of each cell 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 discourage the development of ideal habitats for aquatic plants.

Inside slopes of the cells should be armoured, where required, to prevent erosion. The impact of ice formation on winter storage should be accounted for in the design.

3. Reservoir Management

The owners of raw water reservoirs should 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.

The reservoirs should be managed to avoid any difficulties with algae, 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 should be adopted to improve the water quality. Use of algaecides is not allowed due to the toxicity of the algaecide and the potential for algae cells to be ruptured resulting in the release of cyanotoxins from certain species of algae.

4. Lining

Raw water reservoirs should be designed to minimize seepage. Reservoirs should be lined in accordance with Section 4.2.1.4 pertaining to wastewater stabilization pond liners. This standard is based upon AESRD's publication entitled Design and Construction of Liners for Municipal Wastewater Stabilization Ponds.

2.2.5 Groundwater Supply

2.2.5.1 Siting of Wells

Wells should be located to avoid proximity to sources of pollution and/or flooding. Wells shall 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 shall be provided for repair and maintenance.

2.2.5.2 Well Protection

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

1. Watertight construction to at least 2 m below ground level. This depth may be increased if local conditions present a danger of surface contamination;
2. an annular opening of at least 40 mm outside the protective casing, filled with an approved grouting material; and
3. other precautions in the design to seal off undesirable subsurface formations and surface contamination.

2.2.5.3 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. In addition, the following special considerations apply:

1. The elevation of the top of the production well casing should be 200 mm above the established ground level or the pumphouse pit floor, and at least 200 mm above the highest recorded flood level;
2. A pump pedestal should be provided around the surface casing to support the full weight of the pump and to prevent any weight from being placed on the production casing or any associated well casing;
3. A water-tight seal should be provided between the pump base plate (or submersible discharge head) and the pump pedestal, and between the well casing and the pump discharge column to prevent the entrance of contaminants;
4. An aperture for air venting with proper screening should be provided to the production well surface casing. Where there are indications of excessive quantities of explosive or toxic gases in the water, both the well casing and pump columns should be vented to the outside of the pumphouse (protection against freezing is required);
5. Return pipes that will permit water to be recirculated down the well should be avoided as they may cause contamination of the well. In cases where recirculation is proposed because of severe water shortages, the proponent should provide design details with the application for a permit;
6. The well should not be located within 1.2 m of an exterior wall of the pumphouse, and should be centred under a hatchway in the roof which is at least 1 (one) metre square to

facilitate access. Also, to accommodate redevelopment of wells, access for service rigs should be provided;

7. Well water quality monitoring should be provided by including a suitable sampling point. Water level monitoring should be provided by including at least one opening in the well head which allows vertical access to the inner casing for equipment installation;

8. Either an electric resistance tape or a water level measuring airline should be installed (clamped to the pump column) complete with a suitably calibrated pressure gauge;

9. The piping layout in the pumphouse should include an in-line free discharge pipe to the outside of the building to permit future testing of the well; and

10. A flow measurement device should be provided.

2.2.5.4 Well Disinfection

Prior to the use of a water well for domestic consumption, the well should be disinfected. 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 computed on the basis of water required to provide mixing throughout the entire well volume.

2.3 Water Treatment

2.3.1 Rapid Sand Filtration

The following guidelines have been prepared to document the desirable ranges, and the normal, minimum or maximum acceptable levels for the various design parameters used in the design of rapid sand filtration systems. This document is not a design manual per se as documentation of all parameters relating to water treatment plant design is beyond the scope of these guidelines, but an attempt has been made to include the parameters of greatest importance from the process and reliability standpoints as a guide.

2.3.1.1 General Guidelines

Process Selection

1. Raw Water Characteristics

   The raw 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, a thorough evaluation of the raw water types should precede the selection of a treatment process. The major raw water characteristics are microbiological quality, turbidity, pH, alkalinity, colour, TOC, TSS, iron, manganese, algal counts, temperature and UV absorbance at 254 nm.

   Preferably at least a five-year history that characterizes the main raw water types should be collected. While this 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 that are located upstream and/or downstream from a proposed site may provide valuable information on the raw water characteristics.

2. Enhanced Coagulation

It is recommended that treatment plants using surface waters/GWUDIs should practice enhanced coagulation for disinfection by-products (DBP) precursor removal. TOC content of the source water is generally a good predictor of DBP formation potential, and enhanced coagulation is based on the organic content and driven by the TOC levels. Pre-chlorination should not be practiced at high TOC levels.

Enhanced coagulation is defined by achieving the removal percentages prior to the point of continuous disinfection given the source water alkalinity and TOC concentrations as shown on Table 2.2.

TABLE 2.2: TOC Removal Percentage

Influent TOC mg/L	**Influent Alkalinity, mg/L**		
	0-60	**60-120**	**> 120**
0-2	No action	No action	No action
2-4	40%	30%	20%
4-8	45%	35%	25%
> 8	50%	40%	30%

3. Coagulant Residuals

Aluminium levels in finished water have become a concern for systems using aluminium-based coagulants, particularly for systems producing water with elevated pH. Thus, municipalities should take steps to reduce the amount of aluminium below Health Canada's Operational Guidance Value of 100 µg/L, in the finished water, especially for those plants practicing lime softening.

4. Jar Tests

As bench-scale testing of the treatment often gives meaningful insight to full-scale results, it is recommended that jar tests be done on the raw water. For high TOC waters, jar tests should investigate TOC or UV_{254} removal as well as turbidity removal. Jar test data should statistically establish the treatment requirements of the source water with respect to the process and the water treatment chemicals that are being proposed. The recommended apparatus are a paddle type jar tester, 2.0 litre square beakers, and automatic pipettes. Provisions should be made to ensure that the water temperature during the jar tests is constant and representative of the design conditions. A description of the techniques used, the jar tests results and the conclusions made based on the jar tests should be included in the pre-design report.

5. Pilot Tests

Where practical, pilot studies should be conducted, and specifically when a non-conventional treatment process is proposed or a new water source is being developed. Piloting should be done for sufficient length of time to statistically verify the proposed treatment process. A description of the apparatus, the results and the conclusions made based on the pilot studies should be included in the pre-design report.

Optimization Capability

Unit processes should be designed in order to provide the operator with the flexibility to optimize and integrate each unit. Package plant installations should not be excluded from the requirement to provide the same optimization capabilities as larger plants.

Bypasses to waste should be provided for each process unit and the piping sized for the design capacity of the unit.

Manual or automatic sampling capabilities should be provided at each stage of the process. Multiple sampling locations should be provided for a unit such as a clarifier or flocculator.

Prior to commissioning, a tracer study should be conducted in order to prepare a blueprint of the plant hydraulics that can be used for plant optimization and for troubleshooting future problems. A tracer study should be performed at the initial and at the design flow rate and should quantify actual detention as opposed to theoretical detention times for each operating unit. As an alternative, tracer data supplied by the manufacturer for package plants and proprietary systems would be acceptable. The data from the tracer studies should be included in the as-built plans and/or the operating manual.

For plants with throughput in excess of 10 ML/d, an actual hydraulic grade line at initial and design flow rates should be measured. This data should be submitted with the design hydraulic grade line as part of the as-built plans and/or the operating manual.

Plant Automation

Computer control systems should be provided for all new and upgraded water treatment plants. These will enable the operator to monitor and/or change critical plant operating parameters by means of a computer or a programmable logic controller. Section 2.3.5.3 identifies those parameters for which monitoring may be automated.

2.3.1.2 Chemical Mixing and Coagulation

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 raw 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.

Some general comments pertinent for the design of chemical mixing and design criteria for various types of rapid-mix units are as follows:

1. General Comments

   a. The designer should establish the initial and ultimate design flow capacities for each of the different raw water types. The mixers that are selected should be capable of delivering the required energy input for each of these flow rates and raw water types. Unless it can be demonstrated that raw water quality and plant throughput will not significantly change, the rapid mixer should be capable of delivering a range of energy inputs.

b. Simultaneous addition of a primary coagulant and a flocculant aid to a single rapid mixer is not recommended. An optimum time of separation should be derived from jar or pilot tests or should be at a minimum of two minutes. It is not unusual to add flocculant aids at the flocculator.

   Flocculant aids should be mixed into the process stream either mechanically or hydraulically and a maximum energy of mixing should be determined so as not to shear the polymer chain.

c. Dilution of polyaluminum coagulants is not recommended. To avoid precipitation of hydroxide forms, alum should not be diluted to below 0.5% (pH of solution is approximately 3.0) and ferric salts should not be diluted to below 2.5% (pH of solution is approximately 2.0).

d. In-line mechanical mixer should be the option of choice for primary coagulants due to its versatility.

   Mixing systems consisting of a back mix rector or a channel with one or more mechanical flash mixers are not recommended for primary coagulants since they usually result in a lack of instantaneous mixing, short circuiting, and a mixing time that is excessive for metal salts. These systems are acceptable for chemicals other than primary coagulants.

e. Injection of chemicals into a pump suction is not recommended since this results in inadequate control of mixing energy and possible pump damage. Hydraulic rapid mixing of a primary coagulant through venturi meters, parshall flumes, weirs and orifices are also not recommended for primary coagulants since these devices provide inadequate control of mixing energy into the process. They are acceptable for chemicals other than primary coagulants.

f. High energy mixing is not required for chemicals that are not used for coagulation. As a guideline these chemicals can be injected a minimum of 30 pipe diameters or channel widths away from the point of coagulant addition.

The materials used in construction of the chemical mixing system should be corrosion resistant.

Static mixers are not recommended for mixing applications with highly variable flow rates, since at low flow rates, insufficient mixing is often provided.

2. Design Criteria

Rapid Mixing for coagulants
$G > 3,000\ s^{-1}$

Rapid Mixing for Polymers
$G = 400$ to $800\ s^{-1}$

3. Scale-up Criteria

Constant value = $N^{5/8} D^{5/9}$

Where:

N = rotational speed, rpm

D = mixer diameter, m

2.3.1.3 Flocculation

Some general comments pertinent for the design of flocculation system and design criteria for various types of flocculators are as follows:

1. General Comments

   a. All systems should employ proper compartmentalization so as to avoid short-circuiting.

   b. Except in very small plants a minimum of two flocculation trains should be provided.

   c. For conventional treatment the flocculation units should be located as close as possible or adjacent to the solids separation units.

   d. The inlet and outlet design should prevent short-circuiting and the destruction of floc.

   e. A drain or pumps should be provided in order to handle sludge removal.

   f. For mechanical flocculators an infinitely variable speed mixer is recommended for the last stage. Two or three speed motors are acceptable for the preceding stages.

   g. Baffles may be used in order to improve the efficiency of mixing. Two or four baffles are recommended and they should penetrate 1/8 to 1/12 of the width across the individual mixer compartment.

   h. Alternative and proprietary designs will be judged on their own merit. Prior to design, pilot testing of the alternative or proprietary systems should be conducted and the results should be included in the pre-design document. As indicated earlier, scale-up based on geometrically similar units with constant $N^{5/8}D^{5/9}$ is recommended.

   i. If there is a significant pH depression, the materials that are used for construction should be corrosion resistant. Alternatively, corrosion control measures (e.g. cathodic protection, coatings) could be used.

   j. Diffused air systems are not recommended due to the high rate of energy consumption and inefficiency. An exception would be if volatile inorganic or organic compounds need to be removed.

   k. Water jet mixing is not recommended due to the high shearing force of the jet that tends to restrict floc size.

   l. Hydraulic flocculators are not recommended for applications with highly variable flow rates; insufficient flocculation energy is often provided.

2. Design Criteria

a. Vertical Turbine Flocculators

$G = 100$ to $10\ s^{-1}$ (tapered)
t = 15 to 40 minutes (for conventional treatment)
G x t = 20,000 to 200,000
Stages = 2 (for direct filtration applications) to 4, typically 3
Maximum tip speed = 2.0 m/s
Blade Area/Tank Area = 0.1% to 0.2%
D/T = 0.2 to 0.4 (D = blade length, T = equivalent tank diameter)
Shaft speed = 8 to 25 RPM

- Recommended for direct filtration (higher energy/shorter detention time) and conventional systems (lower energy/longer detention times).

b. Horizontal Paddle Flocculators

$G = 50$ to $10\ s^{-1}$ (tapered)
t = 30 to 40 minutes
G x t = 20,000 to 110,000
Floc stages = 3 to 2
Maximum tip speed = 1.0 m/s
Blade Area/Tank Area = 5% to 25%
Shaft speed = 1 to 5 RPM
Minimum number of paddles per shaft = 3

- Recommended for conventional treatment systems.

Note: Baffled Walls for Mechanical Mixers

Typical orifices size = 100 mm to 150 mm, rectangular or round, evenly distributed.
Maximum velocity of water through the orifices in the first stage 0.20 m/s
Maximum velocity of water through the orifices in the last stage = 0.35 m/s.

Maximum velocity of water through orifices that connect directly into a sedimentation tank = 0.25 m/s.
Headloss through the ports should be less than 1 cm in order to prevent floc break up.
At the bottom of the baffle, clearance should be provided for the washing and removal of sludge.
The top of the baffle should be slightly submerged in order to promote the passage of scum.
Baffled walls contribute a G of 5 to 25 s^{-1} and this may be incorporated into the overall mixing requirement.

c. Baffled Channel Flocculators or Hydraulic Flocculators

Commonly called "around-the-end" or "over and under"

"G" = 12.7 $(h/t)^{0.5}$ at 4^o, where t = residence time in seconds, and h = headloss in metre

G = 50 to 5 s^{-1} (tapered)
t = 20 to 45 minutes
Maximum flow velocity = 1.0 m/s, downstream sections will have much lower velocities.
Typical headloss = 0.2 to 1.0 m
Minimum water depth = 3.3 m
Minimum distance between baffles = 0.75 m
Minimum number of channels = 2
Typical headloss across the tank = 0.3 to 0.2 m

- Recommended for conventional treatment where plant flow variation is small.

- Adjustable baffle walls are recommended for varying raw water conditions.

2.3.1.4 Solids Separation

1. Sedimentation

Some general comments pertinent for the design of sedimentation/clarification system and design criteria for various types are as follows:

a. General Comments

i. The minimum number of sedimentation tanks should be two in separate trains with dedicated filters except in very small plants.

ii. Bottom slope can vary from <1% to 8% depending on the sludge removal method.

iii. Sludge should be automatically removed by mechanical means. Steep sided hoppers shaped bottoms (e.g. >45º) by themselves are inadequate for sludge removal unless the sludge bed is not allowed to compact.

iv. Installation of a grit chamber at the low lift pumps is recommended if raw water contains a large amount of silt and sand.

v. If there is a significant pH depression, the materials that are used for construction should be corrosion resistant. Alternatively corrosion control measures (e.g. cathodic protection, coatings) are recommended.

vi. An overflow to waste should be provided.

vii. A by-pass for the sedimentation unit may be provided to permit direct filtration during maintenance of the tank or when water conditions are suitable for direct filtration. Disinfection should be capable of providing the required inactivation of *Giardia* and *Cryptosporidium* during the direct filtration mode.

b. Design Criteria

i. Horizontal-flow type (Rectangular basin without high rate settling modules)

Surface Loading Rate = 0.83 to 2.5 m/h
Water Depth = 3 to 5 m
Detention Time = 1.0 to 3 hours
Length/Width = Minimum 4/1, Recommended 5/1
Maximum Length = 75 m
Maximum Width = 25 m
Freeboard = 0.2 m (typical)
Weir Loading < 11 m^3/m.h.
Reynolds Number <2000
Froude Number >10^{-5}

Due to the potential for short-circuiting and dead spaces, rectangular basins should not be designed with 180º horizontal bends along the flow path.

ii. Horizontal-flow type (Rectangular basin with high rate settling modules)

Surface Loading Rate (Flow/Projected area of basin covered by modules)
= 2.3 to 5.0 m/h (cold water: < 10ºC)
= 7.5 to 8.8 m/h (warm water: > 10ºC)

Water Depth = 3.2 m (minimum due to mechanical sludge removal) to 5.0 m.
Maximum Area Covered by Tube or Plate Settlers = 75%, from the back wall forward to the inlet.
Weir (Launderer) Loading <15 m^3/m.h.
Approach velocity to modules = 0.2 m/min (typical)

- Higher surface loading rates may be acceptable when a heavy floc is generated. Natural conditions or the use of a flocculant aid can produce rapidly settling floc.
- The surface loading rate is also a function of the type of high rate settling module.
- A continuous sludge removal system is recommended if high rate settlers are employed.
- Due to the potential for short-circuiting and dead spaces, rectangular basins should not be designed with 180^o horizontal bends along the flow path.

Note:

A. For perforated inlet baffles in rectangular basins that are not part of the flocculator

    - Ports should be uniformly distributed across the entire cross section.

- While maintaining the structural integrity of the baffle wall, a maximum number of ports should be provided in order to minimize the velocity of the jets and the dead zones between ports.
- Maximum velocity of the water jet entering the sedimentation tank should be 0.25 m/s.

B. For long rectangular tanks, provision should be made for the design and installation of an intermediate diffuser wall(s). These walls may be installed at or after plant start-up.

C. For Outlets for Rectangular Basins

- Long finger launderers with or without adjustable weir plates are recommended.
- Submerged orifice pipes and troughs are acceptable.
- Significantly higher weir loading rates may be allowed if the weirs are evenly distributed over a substantial portion of the surface (20% to 70%).

iii. Up-flow Type (Radial, without high rate settling modules)

Circular or square in shape
Surface loading rate = 1.3 to 1.9 m/h
Water Depth = 3 to 5 m
Detention time = 1 to 3 hours
Weir Loading < 7 m^3/m.h.

- These are usually proprietary designs.
- Recommended for plants where raw water flow and quality is constant.

iv. Reactor Clarifier

Flocculation time = 20 minutes, and up to 40 minutes in cold water
Surface loading rate < 3 m/h for alum/ferric coagulants
Detention time = 1 to 2 hours
Weir Loading < 15 m^3/m.h.

- These are usually proprietary designs.
- Tube settlers may be added in order to improve performance as plant throughput increases.
- Recommended for water softening or conventional treatment where the raw water quality is constant.

v. Solids Contact Clarifiers (with high rate settling modules)

Flocculation time = 20 minutes typically and up to 40 minutes in cold water
Surface loading rate < 5 m/h for alum and < 9 m/h for lime

Detention time = 1 to 2 hours
Weir Loading = 7.5 to 15 m^3/m.h.
Slurry recirculation rate = 3 to 10 times the raw water inflow rate

- Surface loading rate may be reduced in cold weather conditions
- Lower values for recirculation are used for coagulation.
- Higher values for recirculation are used for lime/soda ash softening.
- These are usually proprietary designs.
- If high rate settling modules are not used, the loading rates would be about a third of what is recommended.
- Recommended for water softening or conventional treatment.

2. Dissolved Air Flotation (DAF)

a. General Comments

i. The minimum number of DAF units should be two.

ii. DAF is a particularly useful process where the floc is light (such as often occurs with low-turbidity raw waters) or where the suspended particles (such as algae) tend to float rather than sink.

iii. Uniform withdrawal of the clarified water, from the bottom area of the units, is recommended to minimize short-circuiting.

iv. DAF should be considered only in conjunction with chemical pre-treatment.

v. Suitability of DAF for a particular raw water source should be substantiated/verified by a pilot study.

b. Design Criteria

i. Bubble diameter = 20 to 100 microns

This is typically achieved by air saturation in a pressurized vessel; larger bubbles will shear rather than float the floc particles.

ii. Surface loading rate = 5 to 15 m/h

Dependent on factors such as water quality and temperature, tank configuration, and size and characteristics of suspended particles.

iii. Saturation pressure = 450 to 725 kPa

Recycle rates = 6 to 10% of the total process flow

Air requirements = 8 to 10 grams/m^3 of raw water

Design of the recycle water injection nozzles shall ensure even distribution across the inlet, and minimize tendencies for the air bubbles coalesce near the point of injection.

iv. Inlet baffle should be placed at an angle greater than 45º to the horizontal (typically 60º to 75º).

Cross flow velocities between the top of the weir and the water surface = 0.7 to 1.0 m/min.

v. Floating sludge removal system - Mechanical removal by reciprocating scraper.

Hydraulic removal will result in dilution of the waste sludge.

2.3.1.5 Filtration

1. Filtration Systems

Where possible, the filtration system should be designed and operated to reduce turbidity levels as low as possible, with a goal of treated water turbidity of less than 0.1 NTU at all times.

There are basically three types of rapid sand filtration systems. They are: declining rate filtration; influent flow splitting; and constant rate filtration.

a. Declining Rate Filtration

In declining rate filtration, filter influent enters through specially designed manifolds to provide virtually equal head to all filters. The filter outlet contains a restriction limiting filtration rate through a clean bed to the maximum allowable rate, and filtration rate declines as the bed plugs. An advantage of this method is that it avoids potential water quality deterioration caused by high shearing forces on a dirty bed which can occur in constant rate filtration as design headloss is approached. Disadvantages include the need for special care in start-up of filters by gradually opening of the effluent valve, and a loss of operating flexibility, which is particularly significant in larger plants.

b. Influent Flow Splitting

Influent flow splitting employs free fall weirs as a means of providing equal flow to multiple filters, thus avoiding the need for, and cost of, effluent control systems. The disadvantages include the potential for flocculated particles to shear passing the weir, thus impairing the filtration process; and that weir settings are normally made to accommodate a single plant flow rate. Changes in plant flow cause different losses in influent channels and the influent flow are no longer equally divided.

c. Constant Rate Filtration

The most commonly used method is known as constant rate filtration. In this method the filter effluent piping contains a flow measuring device, frequently a venturi flow meter, and an automatically controlled modulating butterfly valve. The filtration rate is set to a pre-determined value by positioning the effluent valve accordingly and filtration is continued at that rate by the effluent valve gradually opening to compensate for increased headlosses as the filter bed plugs. The rate is maintained until clearwell level exceeds a level typically 300 mm below the design top water level. At this point the filtration rate decreases proportionally to the 'freeboard' in the clearwell until the filter reaches its lower operating limits at which time it is shut off. This should be set to occur just before the clearwell is full.

2. General Design Consideration

The design of gravity filters should provide:

a. adequate headroom above the filter to permit inspection and operation and maintenance, and provide reasonable access to the filters for observation (e.g., a walkway along the length and width of the filters for package plants),

b. an overflow sized for the filter/plant capacity to prevent flooding, unless provided elsewhere in the raw water supply system and relief from flooding caused by improper operation of the backwash pump,

c. means of cleaning influent pipes or conduits where solids loadings are high,

d. effluent piping designed hydraulically for flows of up to 50% in excess of filtration design capacity to accommodate potential peak demands, provided that the water quality is not compromised,

e. effluent piping arranged to prevent backflow of air into the filter,

f. piping for filter to waste to be designed at full filter flow capacity,

g. design to accommodate measurement of turbidity during production and filter-to-waste modes,

h. operation with a minimum water depth in excess of the design terminal headloss to prevent negative pressure and air binding of the filter as described in subsection 5 – Headloss,

i. an acceptable method of regulating flow as described in subsection 1 - Filtration Systems, and

j. controls as described in Section 2.3.5 - Controls and Instrumentation.

Wash water troughs should be designed so that a clearance is maintained between the bottom of the trough and the level of the expanded media during backwashing.

The bottom of trough to the top level of the static media should not be less than 200 mm, and in some cases should be higher, and the trough capacity should be such that the maximum wash water rate can be accommodated with at least 50 mm freeboard. Trough spacing should be such that each trough serves equal filter areas, and a maximum horizontal travel for suspended particles to reach a trough of 1.0 m is recommended. Troughs should be located so that they do not obscure filters or affect accessibility.

3. Filter Media

The quality of filtered water is a function of both media size and media depth. The selection of filter media determines not only the filter effluent quality but also the filter backwash regime, and thus the backwash requirements become an integral part of the media decision. For instance, the greater the uniformity coefficient of the media, the larger the backwash rate required to fluidize the coarser grains thus provided.

Dual-media filters have some advantages over single-media filters in terms of filter run lengths, headloss, hydraulic loading rate, etc. For dual-media filters, the size of the sand layer shall be selected to be compatible with the anthracite that has been selected. The bottom sand layer should have approximately the same or somewhat higher flow rate for fluidization than the anthracite to ensure that the entire bed fluidizes at the selected backwash rate. Further, the effective sizes of the sand and anthracite should be selected to achieve the goal of coarse-to-fine filtration without causing excessive media mixing.

The particle size and the depth of the media selected for a given filter application depends on the kind of suspended solids to be removed by the filter. This is best established by pilot studies. Typical design data is shown in Table 2.3.

Sieve analyses should be performed and the values plotted to ascertain sand size distribution.

Deep bed filtration, i.e. > 2.0 m, may be used in conjunction with the policies and procedures outlined in AESRD's policy - Unproven or Innovative/Alternative Technologies.

4. Filtration Rates

Filter loading rate is an important parameter in the design of a water treatment plant; and in general the filters may be designed to be operated with the loading rate in the range 2 m/h to 9 m/h.

Low filtration rates do not ensure good quality of water; what is more critical is the chemical pre-treatment and the filter design. With adequate chemical pre-treatment and filter design, filtration rate of up to 15 m/h may be applied without deterioration of the filtrate quality. However, high-rate filtration (i.e. 9 m/h < rate < 15 m/h) should be substantiated by a filter column study using the proposed source water under the full range of anticipated water conditions.

Filtration rates higher than 15 m/h may be used only in conjunction with the policies and procedures outlined in AESRD's policy - Unproven or Innovative/Alternative Technologies.

TABLE 2.3: Typical Design Data For Dual-Media Filters

	RANGE	**TYPICAL**
Anthracite		
depth, mm	300 to 600	450
effective size, mm	0.8 to 2.0	1.2
uniformity coefficient	1.3 to 1.8	1.5
Sand		
depth, mm	150 to 300	300
effective size, mm	0.4 to 0.8	0.5
uniformity coefficient	1.2 to 1.2	1.4
Ratio of coal size to sand size (D_{90} coal/D_{10} sand)	-	3

5. Headloss

The total head available or head loss on a filter is the difference in elevation between the water levels on the inlet and outlet side of the filters. This is a critical parameter for influent flow splitting and constant rate filters. For a specific media and flow rate, the total headloss and the time to reach a fixed headloss depend on the volume of floc retained by the filter. Thus headloss is closely associated with the filter run lengths; operation of a filter with long filter runs and high headlosses will result in break-through of the flocs.

Typical headloss for gravity filtration may be in the range from 0.3 m (clean bed) to 2.5 m (final). The filters may be operated with run lengths between 12 and 72 hours, with 24 hour runs being typical.

If the headloss at any level in the filter bed exceeds the static head, a vacuum is created, resulting in air binding in the zone of negative pressure. In order to eliminate the problem of negative pressure, the filter should be designed to discharge the effluent water at a level above the sand media surface.

6. Filter Backwash

Three basic methods are available for filter backwash: Up flow water wash without auxiliary scour, up flow water wash with surface wash, and up flow water wash with air scour. The suitability of a washing method is related to influent water quality, filtering media and bed configuration, and underdrain design. Consequently, not all washing methods are applicable in all cases, and different methods may or may not yield similar results in a particular case. Declining rate backwash systems are not acceptable.

Required backwashing rates are variable and depend on water temperature, filter type and washing method. Water velocity required to achieve the same bed expansion increases as the temperature increases, thus backwash systems should be designed for the warmest wash water temperature.

a. Up flow Water Wash Without Auxiliary Scour

For the washing to be effective, backwash rate should be sufficient to fluidize the bed with 30 to 40% expansion. The relatively weak cleaning action of water wash without auxiliary scour generally renders it unsuitable for filters removing large quantities of suspended solids.

When water wash is used alone, a rise rate of 32 m/h to 54 m/h should be applied. Backwash duration may vary between 3 to 15 minutes, depending on how dirty the filter is.

b. Up flow Water Wash With Surface Wash

Surface wash is generally applied to supplement up flow backwash where mud ball formation is likely to be a problem. Either a fixed-nozzle or rotary wash system may be used; rotary systems are preferred because they provide better cleaning action, lower water requirements, and less obstruction for filter access.

For optimum results, a combined surface and water wash should be designed to be operated in three phases. First, surface wash is activated and operated alone for 1 to 3 minutes. Water wash is then applied simultaneously at a low rate to achieve a bed expansion of less than 10 percent for 5 to 10 minutes. The final phase involves application of wash water only at a higher rate to achieve 30 to 40 percent bed expansion for 1 to 5 minutes.

Rotary surface wash system should be designed to add 1.5 m/h to 2.0 m/h to the wash water flow; and, fixed nozzle system to deliver 2 m/h to 9 m/h.

Because surface wash systems constitute a possible connection between filtered and unfiltered water, backflow prevention devices shall be provided in supply lines.

c. Up flow Water Wash With Air Scour

There are three approaches to use auxiliary air scour in backwashing filters.

Air scour alone for 3 to 5 minutes followed by low-rate water wash for 5 to 15 minutes could be applied for single media-filters with 0.2 to 1.2 mm media. Air scour should be designed to inject air at 18 to 27 $m^3/m^2.h$; and water wash at 12 m/h to 18 m/h.

The second approach, which is suitable for dual-media filters, is to apply air scour alone for 3 to 5 minutes followed by water wash for 5 to 10 minutes. Bed stratification would occur during backwash cycle. The air scour should be designed to inject air at 54 to 90 $m^3/m^2.h$, and water wash at 12 m/h to 18 m/h.

The third approach is to have simultaneous air scour and water wash followed by water wash alone. During the initial stage, air scour rate of 18 to 90 $m^3/m^2.h$ should be used with a water flow of about 18 m/h for approximately 5 to 10 minutes. This is followed by water wash only for about 5 to 10 minutes at a rate of one to two times that of the previous cycle used with air scour.

2.3.1.6 Flow Measurements

Flow meters should be provided on:

1. the main raw water supply line to measure the total flow entering the plant;

2. individual filters. This may be necessary for constant rate filtration to ensure that each filter receives the same flow; and for declining rate filtration to initiate backwashing of filters;

3. the combined filter effluent line and/or on the distribution main head to measure water usage by the community; and

4. the backwash line to measure and check the volumes of water used for backwashing the filters.

2.3.2 Slow Sand Filtration

The slow sand filter is a sand filter operated at very low filtration rates, frequently without the use of coagulation in pre-treatment. The sand used is smaller than that for a rapid filter, and this, plus the low filtration rate, results in the solids being removed almost entirely in a thin layer on the top of the sand bed. This layer, composed of dirt and micro and macroorganisms from the water (i.e. the schmutzdecke), becomes the dominant filter medium as the filter cycle progresses.

When the head loss becomes excessive, the filter shall be cleaned by draining it below the sand surface and physically removing the schmutzdecke. Typical cycle lengths may vary from 3 to 6 months depending on the source water quality and the filtration rate.

2.3.2.1 Requisite Conditions

Source water quality and community size are the key factors that should be considered in the selection of slow sand filtration to treat surface water.

1. Water Quality

   Raw water quality determines the length of time between scraping options, and slow sand filtration shall be limited to raw waters that will permit filter runs of at least three months before terminal headloss is reached.

   The mix of water quality characteristics causing headloss is unique to each situation and cycle lengths cannot be predicted without pilot plant testing. Unless specifically exempt by AESRD, suitability of slow sand filtration for treatment and run-length shall be ascertained by pilot testing to cover all four seasons of the year.

   Some waters with high algae content form a mat on the filter surface causing a rapid increase in headloss. Further, the decay of algae on the schmutzdecke may cause taste and odour problems in the effluent water. Thus source waters subject to algae blooms may not be acceptable for slow sand filtration unless the bloom season is short enough that only minimal interruption of normal operation is likely.

   Though low turbidity of source water is not always indicative of long filter run-lengths, water with high turbidities can blind off the filter with a layer of sediments on top of the filter bed. Thus source waters with high turbidities may not be acceptable for slow sand filtration, unless the turbidities are attenuated by the use of sedimentation basins or roughing filters.

   Slow sand filtration is not effective in removing colour, and source waters with high colour are not acceptable for slow sand filtration.

   Slow sand filtration is ineffective in removing dissolved organic carbon, and because of potential disinfectant by-products, source waters with high dissolved organic carbon (DOC) may not be acceptable for slow sand filtration if chlorination is practised for disinfection. However, in some cases, ozone ahead of slow sand filtration has proven to increase run length and increase biodegradation of organic compounds, i.e. DOC converted to BDOC. This is considered an alternative technology and will be approved only in conjunction with the policy, "Unproven or Innovative/Alternative Technologies" in the Municipal Policies and Procedures Manual.

2. Community Size

Slow sand filtration is considered appropriate for use by "small" communities. At some point in population size, slow sand filtration becomes more expensive than rapid sand filtration. Also, at some point as population increases, communities will have the requisite resources to effectively and reliably operate a rapid sand filtration system. The point of crossover on both curves depends upon the community context, and should be considered in ascertaining the suitability of slow sand filtration for that community.

2.3.2.2 Filter Media

Ideally the effective size (D_{10}) of the sand should be just small enough to ensure a good quality effluent and to prevent penetration of clogging matter to such a depth that it cannot be removed by surface scraping.

The recommended sand size is D_{10} = 0.2 to 0.3 mm with uniformity coefficient (UC) = 1.5 to 2.0. Media having a sand size with D_{10} $\geq$0.3 mm and UC >2 may be acceptable if a pilot study ascertains that acceptable removals are obtained.

The sand being considered should be washed to remove dust/fine particles to avoid long start-up times. Sieve analysis should be performed and the values plotted to ascertain sand size distribution.

2.3.2.3 Filter Depth

The depth of sand bed is determined by the number of years of operation desired before re-sanding is needed. The years of operation are calculated as follows:

$$Y = \frac{Di - Df}{R.f}$$

in which Y = period of operation, yr
Di = initial sand bed depth, mm
Df = final sand bed depth, mm
R = sand depth removal per scraping, mm
f = frequency of scraping, number/yr

Generally sand bed depth should be between 1 to 1.3 m in depth at the start of operation, a deeper bed may be used if desired. The minimum bed depth should be greater than 0.5 m, assuming the filter is biologically mature. A staff gauge to measure sand bed elevations should be placed on the wall/bank of the filter to denote minimum and maximum sand levels.

2.3.2.4 Filtration Rates

Hydraulic loading rate for the maximum daily design flow may vary between 0.1 m/h and 0.4 m/h. The system should be designed so that when one of the filters is removed from operation for scraping, the combined loading rate of the remaining filters may not exceed the design filter hydraulic loading rate. While the hydraulic loading rate may vary during the annual cycle and generally increase as the population grows, the flow should be steady over the daily cycle.

2.3.2.5 Headloss

Headloss within a slow sand filter is caused by flow through the schmutzdecke and the sand bed; but mostly through the schmutzdecke.

The clean bed headloss is usually about 0.01 m, depending on the hydraulic loading rate, the temperature and the sand media characteristics. Acceptable headloss limit is economic rather than technical because there is no evidence that higher headloss would cause breakthroughs.

Typical headloss for slow sand filtration may be in the range from 0.1 m (clean bed) to 2.0 m (final). The rate of headloss increase is crucial to the determination of whether slow sand should be selected as the filtration technology because the length of filter runs depend on the rate of headloss increase. This can be analyzed only by pilot plant testing. In general, the rate of headloss increases with time, and the marginal benefits of continuing the filter run decrease rapidly after a certain period.

2.3.2.6 Hydraulics

1. Distribution

   Delivery of the entire flow to a filter to one point in the filter bed would result in bed erosion. The consequence of such a condition is short-circuiting of flow through the sand bed. To control bed erosion, the inlet should be designed to distribute and dissipate the kinetic energy. One approach is to distribute the influent flow around the filter bed; the lateral pipe should be large enough that the exit velocity would be sufficiently low. Distribution pipe should be placed approximately 0.3 m from the top of sand bed. For open basins, the impacts of ice cover must be considered.

2. Collection

   Filters should always operate with a uniform hydraulic loading rate over the sand bed and this is dependent on underdrain collection system.

   Collection of the filtered water is through slotted or perforated pipes surrounded by gravel support. The underdrain system should be designed using the manifold hydraulic principle; that is, the headloss within the main pipe should be small compared with the headloss through the orifices in the main pipe. If this principle were maintained, then the hydraulic loading rate across the filter bed would be uniform.

   Spacing of the underdrain varies from 1.0 m to 2.0 m; closer spacing is preferred, as it would provide an added certainty of uniform loading of the filter.

3. Drainage

   To scrape the sand bed, the headwater shall be drained to a level just below the sand bed surface. Provision should be made in the design to drain the top portion of the headwater directly either through the influent pipes or through a separate pipe.

4. Backfilling after Scraping

After scraping the de-watered filter shall be backfilled with treated water. Provision should be made in the design to backfill the filter through the underdrain system; backfilling from the top can result in entrapment of air bubble which may cause air binding and disruption of the flow.

The treated water may come from an adjacent operating filter or from the clearwater tank. Water from clearwater tank, if used, should be free of chlorine. The headwater should be backfilled to the level of the influent distribution orifices, which is usually placed about 0.3 m above the sand bed to provide the water cushion. Valves and pipings should be provided to accomplish the aforementioned tasks.

5. Flow Control

Flow to the plant should be controlled on the influent side downstream from the influent flow meter. The flow into the plant should be steady over a twenty-four hour period. The treated water storage tank should have an overflow weir with drainage pipeline to waste or recycle, if continuous operation of the filters is desired.

6. Tailwater Control

Tailwater control is necessary so that the water level in the filter can be raised to about 0.3 m above the sand bed immediately after scraping in order to dissipate the kinetic energy of the influent flow.

The design of the system should have a movable weir plate that can be raised or lowered during operation. The initial position of the weir crest, at the start of a filter run, should be about 0.3 m above the top of the sand bed, but the plate should be adjustable enough that it can be lowered to the elevation of the surface of the sand bed once the head loss across the sand bed is greater than 0.3 m.

7. Headloss Measurements

Piezometers should always be installed in filters to measure head-loss. One piezometer should be connected to the headwater above the sand bed, and a second one to the tailwater basin. The piezometers should be 25 to 50 mm in diameter mounted side-by-side, with float balls and scales, to permit easy measurements of water levels.

8. Avoiding Negative Pressures

Negative pressures within the filter bed cause the formation of gas bubbles, which may cause "air binding" and thereby disrupt the flow patterns of water movement through the sand bed.

In order to avoid negative pressures, the system should be designed so that the weir crest for the tailwater elevation control may not be lower than the level of the sand bed during operation.

2.3.2.7 Gravel Support

The function of the gravel support is to support the sand bed and to permit uniform drainage of the overlying sand. In order to have uniform drainage and minimal headloss, the gravel support shall be graded with finer material at the top and coarser material at the bottom.

1. Size

   The gravel support should be designed so that the top layer of the gravel support should not permit migration of sand from the sand bed, nor should the gravel of any layer find its way to a lower level. The bottom layer should not permit entry of gravel to the underdrain orifices. The following rules should be followed in the design of the gravel support layers:

   a. d_{90} (given layer) / d_{10} (given layer) $\leq$ 1.4

   b. d_{10} (lower layer) / d_{10} (upper layer) $\leq$ 4

   c. d_{10} (top layer) / d_{15} (sand) $\geq$ 4

   d. d_{10} (top layer) / d_{85} (sand) $\leq$ 4

   e. d_{10} (bottom layer) $\geq$ 2.d (drain orifice diameter).

2. Depth

   The thickness of each layer should be greater than three times the diameter of the largest stone. At the same time, as a practical matter, the minimum thickness of gravel layers should be 50 to 70 mm for finer material and 80 to 120 mm for coarser gravel.

2.3.2.8 Flow Measurements

Flow meters should be provided on:

1. the influent side for the whole plant; and
2. volumetric flow meter on the exit side for the whole plant.

   The flow meters for the individual filters are used to ensure that each filter receives the same flow and to measure the volumes of water filtered between scrapings. The volumetric flow meter would indicate the amount of water used by the community.

Aesthetic Objectives

Potable water quality should meet the Aesthetic Objectives (AO) in the Guidelines for Canadian Drinking Water Quality, published by Health Canada, as amended or replaced from time to time.

The water distribution system should be cleaned and flushed periodically to keep the turbidity less than 5 NTU.

2.3.3 Lead and Copper

Waterworks system should produce non-corrosive water to minimize lead and copper corrosiveness. It is recommended that the owners conduct corrosion control studies unless they can show that corrosion control is already optimized. Corrosion control studies should compare the effectiveness of pH and alkalinity adjustment, calcium adjustment, and addition of a phosphate or silica-based corrosion inhibitor.

The owners should work with AESRD to establish a protocol for optimizing corrosion control.

2.3.4 Iron and Manganese Control

Iron and manganese exist in water in both the insoluble and soluble oxidation states. The insoluble iron and manganese are readily removed by filtration. However, the removal of soluble iron and manganese poses a more serious problem, particularly when these metals are organically bound.

Presence of soluble iron and manganese in water may lead to complaints from the consumers as a result of staining of laundry or bathroom fixtures. Water containing iron and manganese also promotes the growth of iron bacteria in mains, with accompanying increases in friction loss.

2.3.4.1 Removal of Iron and Manganese

1. Oxidation/Filtration

   Removal of soluble iron and manganese by contact adsorption using pre-coated filter media is the option of choice for treating waters with moderate amounts of iron and manganese in groundwater (<5 mg/L of iron and <1 mg/L of manganese). The filter media that could be used are:

   a. Manganese greensand (natural greensand coated with manganese dioxide);

   b. Pyrolusite (pure manganese dioxide).

   Key to the success of contact oxidation process is the re-generation of manganese dioxide coating on the media, either on a continuous basis or on an intermittent basis.

   Dual media filtration is recommended if iron removal is the main objective. Continuous regeneration operation is also recommended where iron removal is the main objective with or without the presence of manganese. This method involves the feeding of a pre-determined amount of an oxidant (potassium permanganate or chlorine), directly to the raw water prior to the filters. If chlorine is used for waters containing ammonia, sufficient chlorine should be fed to go beyond breakpoint to produce free chlorine for regeneration of the media. The oxidant demand should also be determined taking into consideration the presence of DOC and H_2S.

TABLE 2.4: Design Criteria for Iron and Manganese Removal

Design Parameter	Main Component To Be Removed	
	Iron	Manganese
Regeneration of media	Continuous	Intermittent
Bed type	Dual media	Single media
Depth of bed	Anthracite - 375 to 450 mm MnO_2 media - 450 to 200 mm	MnO_2 media > 750 mm
pH	2.2 to 8.5	7.0 to 8.5
Filter loading rate *	4 to 13 m/h	4 to 13 m/h
Headloss	1.5 m (maximum)	1.5 m (maximum)
Backwash	Sufficient for 40% bed expansion	Sufficient for 40% bed expansion

*a. The higher the concentration of iron and manganese, the lower the loading rates for equivalent run lengths. For optimum design parameters a pilot plant shall be operated.
*b. For intermittent regeneration process, higher loading rate of up to 2.0 m/h may be allowed depending on raw water conditions.

Intermittent regeneration is recommended for waters where only manganese or manganese with small amounts of iron is to be removed. This method involves feeding of a pre-determined amount of an oxidant after a specified quantity of water has been treated. Frequently, intermittent regeneration is done during the backwash cycle. Typical design criteria for iron and manganese removal using oxidation/filtration process are shown in Table 2.4.

2. Aeration/Chemically Assisted Filtration

Aeration followed by chemically assisted filtration is effective in treating waters with fairly high content of iron (>5 mg/L) and manganese (>1 mg/L). Without coagulation and flocculation, the oxidized iron may take 12 to 24 hours or more for effective settling, whereas in properly coagulated water, settling will take place in approximately two hours. If manganese is present, pre-treatment with one or more oxidants (chlorine, chlorine dioxide, potassium permanganate or ozone) is required.

Design criteria are similar to the requirement outlined in Section 2.3.1 - Rapid Sand Filtration.

2.3.4.2 Control of Iron and Manganese

Iron and manganese concentrations in drinking water may be controlled by blending water from different sources so that the combined iron and manganese concentrations are below the aesthetic objectives stipulated in the GCDWQ.

If iron and/or manganese control with sequestering agents is proposed, the total concentrations may remain greater than the aesthetic objectives. Sequestering is generally ineffective with hard waters; pilot testing may be required to verify the performance of the proposal.

2.3.5 Controls and Instrumentation

2.3.5.1 General

Controls and instrumentation should be appropriate for the plant size, complexity, criticality, and number of staff and their skills for each plant. To achieve this, the designer should develop a control philosophy that will enable the plant staff to effectively monitor and control the plant and major equipment, the treatment process, water production and; plant wastes. The following design guidelines represent a minimum standard that shall be achieved. Specific enhancements may be required depending on the water treatment process employed.

2.3.5.2 Measurement List

For plants of 1 ML/d capacity and greater, the following instruments should be provided as a minimum for the relevant processes listed. For smaller plants, pH measurement and fluoride residual may be by bench testing but all other instruments are appropriate for the relevant processes listed.

1. 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

2. Rapid Mixer:
    - Running and trip indication

3. Flocculators:
    - Running and trip indication
    - Speed if variable speed type

4. Solids Contact Clarifiers:
    - Recirculator speed indication
    - Running and trip indication
    - Level indication
    - Blow down valve status

    Turbidity and pH following clarification

5. Proprietary Clarifiers

    Instrumentation for proprietary types of clarifiers including ballasted flocculation and DAF should be as recommended by the manufacturer. However, effluent turbidity and pH are recommended in all cases.

6. Softening:

- If lime softening is used, pH following recarbonation

Recarbonation CO_2 flow present

7. Filter (granular) 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
- Provide open and close limit switches or position on all filter valves and status on backwash equipment

Filter run time

Filter effluent particle counters are optional but are encouraged.

8. Filter (membrane) Instrumentation:

Instrumentation is normally packaged in with the system to meet the manufacturer's needs. However, the following are recommended regardless:

Turbidity and particle counters on each individual filter train effluent.

Filter train flow rate

Pressure differential

- Filter train status (on-line, backwash, clean, off-line etc.)

9. 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
- Surge protection for air blowers

10. Clearwell & Distribution Pump Instrumentation:

- Level indication for clearwell and other tanks
- 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

11. Chemical Systems:

- Running and trip indication for chemical loading, batching and pumping equipment
- Low and high level indication 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 for carrier water feed systems
- Chemical feed flow rate is mandatory unless day tank is provided
- Chlorine alarm
- UV – provided by the vendor but some additional instruments are usually required such as flow meters and valve status for each reactor.

12. 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 on all major valves, status on all major equipment and security instruments including door switches, remote resets, building temperature switches and smoke alarms.
    - Any additional instrumentation recommended by equipment manufacturers.

2.3.5.3 Degree of Automation in Plant Control

The control system may be manual or automatic or a combination thereof. Regardless, the system should be designed to promote safety of staff and the public, energy efficiency, conserve water, and reduce waste while meeting the treated water quality standards and demands under all anticipated conditions. Discuss the operating philosophy with plant staff and owners to determine the appropriate degree of automation.

In the case of a manual system, all equipment is started and stopped by the operator, all backwash sequences and other process operations are controlled by the operator, and chemical and pump rates are manually adjusted. This requires that the plant be attended continuously while in operation, perhaps with more than one operator.

In the case of an automatic system, all equipment is started and stopped by the control system, with chemical feed rates and pump rates adjusted automatically to maintain the system levels, discharge pressures, etc. This may allow unattended plant operation or operation with few staff, but requires a more complex and expensive control system, with associated maintenance. Provide the ability to manually operate all equipment.

There are a wide range of combinations of manual and automatic control systems. For conventional process systems with rapidly varying raw water conditions, fully automated plants should not normally be considered.

2.3.5.4 Alarms and Status Indication

All alarms shall be latched until the Operator has acknowledged them. If the alarm is indicated by a lamp, it shall flash until acknowledged then remain steady until the alarm clears. If it is indicated on a computer screen, an appropriate colour code or symbol shall be used to indicate for each alarm whether it has been acknowledged. Automated systems should log the time at which the alarm occurred, the time it was acknowledged and the time it cleared. Logs may be printed on paper or recorded electronically.

Valve and equipment status should use a consistent method of symbols and colours, whether the status is indicated through lamps or on a colour computer screen. Be certain that the colour-coding scheme is consistent with any existing equipment displays elsewhere in the plant.

As a minimum, provide the following alarms:

- 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 water level in clarifiers or flocculators
- high torque on process rotating elements (e.g., basin mixers, flocculators, solids contact clarifier recirculator and rakes)
- high water level in process basins and open surface channels
- high and low level in chemical storage tanks
- high and low chemical feed rates
- high flow rate on each individual filter (also low flow rate on declining rate filters)
- high and low water 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 on-line measurements are provided)
- high head loss on the filters (if influent flow splitter or constant rate type)
- trip or failure to run on each pump and process motors
- high and low pressure on the plant discharge line
- high flow rate on the plant discharge line
- chlorine gas detection in the chlorine storage, metering and injector rooms
- chlorine scale low weight (where scales are equipped with transmitters)
- valve operation failure (where valves are provided with limit switches).

More alarms may be required where additional treatment processes are provided. Alarms should be provided for all control system interlocks that can shut down equipment or systems. In plants that are left unattended for periods of time, provide an automatic telephone dialler, cellular communication or pager system for annunciation of alarms.

2.3.5.5 Control Equipment (Automatic Systems)

1. Programmable Logic Controllers and Distributed Controls Systems.

   Automatic systems should use either Programmable Logic Controllers (PLCs) or a Distributed Control System (DCS). The operator interface may be in the form of traditional control panels (i.e.: lights, gauges and switches), electronic control panels (with text and/or graphics) and computers.

2. Operator Interface

   The operator interface may consist of a local hard wired control panel or mimic, character based input/output panel, personal computer or workstation depending on system size, process complexity, control system functions and operator interface manufacturer. Where personal computers or workstations are used, select the hardware based on reliability, software compatibility, vendor support and suitability for continuous operation in the plant environment. Provide the hardware and software necessary to facilitate back up of both the system and the collected data. The operator interface software may provide the operator with interactive control and monitoring of the plant, handle and annunciate alarms, log and trend events and process variables and generate the required reports. Process control and logic should be performed by the PLC or DCS and not the operator interface computer or workstation. Where outside access is provided for remote control of the operator interface or other control components (e.g., PLC) provide adequate security.

3. Communication Networks

   Plant communication networks shall be considered. Installing communication networks may assist operations and maintenance personnel with the following functions:

   - device diagnostic data is available
   - remote calibration is possible
   - device alarm status is available
   - distributed control by locating PLCs or RTUs in close proximity to devices being monitored
   - plant data can be made available for use by management
   - loop error is reduced

Plant communication networks can be broken into four types, Sensor Networks, Device Networks, Control Networks and Enterprise networks. Sensor and Device networks are primarily focused on communication with primary elements such as push buttons, temperature transmitters and valve actuators. Control networks provide backbone communication between computers, PLCs and DCSs. Enterprise networks are, for example, local area networks (LAN) and are used to provide information that help to manage the plant. An example of an Enterprise network would be providing data in a spreadsheet format that can be used to assist management in filling out reports for regulatory monitoring.

2.3.5.6 Network Security

Control system security should be considered for mitigation of internal and external threats. Plant internal security at a minimum should include password protection to the control system, allowing only authorized users into development software, plant control software and enterprise software. Control systems should be connected only if suitable hardware and software security devices are in place to prevent unauthorized access to the system. Control systems that are connected to an intranet or wireless system should include provisions to restrict access to the control system by unauthorized personnel.

After the initial installation, the security system should be monitored and upgraded regularly. Improvements should include the upgrading of firewalls and routers, changing passwords and teaching plant personnel on the importance of network security.

2.3.5.7 Historical Data

The control system's historical data should be stored electronically and backed up on removable media such as tape or compact disk. The historical data, and the necessary hardware and software to access the data, should be kept for a period of time as defined in 1.11.1 - Record Keeping.

Historical data collection should include:

- all parameters required to be monitored in accordance with an Approval or a Code of Practice or defined elsewhere in these documents;
- alarms; and
- operator changes, such as set points or control modes.

Data collection frequency will depend on the parameter being monitored and how quickly the parameter changes. At a minimum, data should be collected at a steady time interval that will allow for recreation of parameter without significant error. Various historian software packages have built-in computer algorithms that will minimize data collection while still maintaining the parameter's trend. The collection frequency should be adjusted to allow for proper tracking of the parameter, e.g. seasonal adjustment of raw water turbidity during spring run off.

2.3.6 Colour Codes for Water Treatment Plant Piping

TABLE 2.5: Recommended Colour Coding for Water Treatment Plant Piping

Piping to be Identified	Basic Colour	Bands	
		No.	Colour
Raw or unfinished water	Dark Green	-	-
Clarified Water	Dark Green	1	Black
Filtered Water	Dark Green	2	Black
Filtered and Chlorinated (Potable) Water	Blue	1	-
Backwash Water	Light Green	-	-
Chemical Feed Lines	Pink	-	-
Coagulant	Pink	1	Black
pH Control	Pink	2	Black
Taste and Odour	Pink	3	Black
Fluoride	Pink	1	Green
Chlorine and Water	Pink	1	Yellow
Chlorine Gas	Yellow	-	-
Plumbing (Waste)	Brown	-	-
Electrical	Purple	-	-
Compressed Air	White	-	-
Heating	Silver	-	-
Fire Protection	Red	-	-
Natural Gas	Orange	-	-

Notes:
1. Entire length of pipe to be painted in basic colour.
2. Bands, if required, are to be placed as follows:
   (a) at 9 m intervals, and/or
   (b) where the pipe enters and leaves a room.
3. Individual bands are to be 25 mm wide, and a 25 mm space is to be left between bands where multiple bands are required.

2.3.7 Laboratory Requirements

All water treatment plants should have laboratory facilities for analytical testing as required in the terms and conditions of the operating approval. The capability of the laboratory should commensurate with the size and the complexity of water treatment operation. Before undertaking the detailed design of the laboratory facility, contact should be made with AESRD to confirm the testing requirements.

Minimum laboratory requirements for surface water treatment plants are as follows:

1. Lab equipment

pH - pH meter
Chlorine - chlorine residual titrator or colorimetric test kit
Turbidity - turbidimeter
Colour - colour meter (spectrophotometer or colour comparator)

Tap aspirator/filter apparatus for colour samples
Glassware (beakers, measuring cylinders, sample bottles, flasks, pipettes, burettes)
Balance (top-loading) - if any chemical has to be weighed out
Clean lab bench area, with sink, adequate lighting, and storage.

2. Lab chemicals/standards

pH butter solutions for calibration
Hydrochloric acid for cleaning pH probes and titrators
Distilled water or reagent grade water for rinsing
Turbidity standards
Colour standards
Reagents for any colorimetric tests
Lab grade dishwashing detergent.

2.3.8 Operational Monitoring

Operational monitoring and associated reporting requirements would be established on a site-specific basis. The nature of the water supply source, the type of treatment system employed and the size/capabilities of the owner should be considered when establishing operational monitoring requirements. Operational monitoring requirements are established both for specific process control purposes, and to ensure that a facility receives good operational attention on a regular basis.

Table 2.6 outlines the operational monitoring requirements that would apply to waterworks systems.

TABLE 2.6: Operational Monitoring Requirements

Parameter	Point of Measurement	Requirement/Objective	Minimum Monitoring
Raw water turbidity	Before addition of any chemical or treatment process	None	See Section 1.10.3.3
Treated water turbidity	Immediately after filtration before entering the Clearwater tank	See Section 1.3.1	See Section 1.10.3.3
Raw water flows	Entering the treatment plant	Not to exceed treatment plant's design capacity	Once per day for total daily flow
Treated water flows	Entering the Clearwater tank or the distribution system	None	Once per day for total daily flow
Raw water *Giardia* levels	Entering the treatment plant	None	See Section 1.2.1.1
Raw water pH	Before addition of any chemical	None	Once per day using grab sampling
Raw water iron and manganese	Before addition of any chemical	None	Once per week using grab sampling
Chemicals used	Feed point	The chemical dosage should not exceed the recommended maximum concentration authorized by AESRD	Volume/Weight/Concentration of chemicals used daily or weekly
Treated water pH	Entering the distribution system	6.5-8.5 (exceptions are acceptable if disinfection is not compromised)	Once per day using grab sampling
Treated water aluminum (if aluminum based coagulant is used)	Entering the distribution system	Not to exceed 100 µg/L for conventional plants, and not to exceed 200 µg/L for other types of treatment	Once per week using grab sampling
Turbidity within distribution system	Random location throughout the distribution system	Not to exceed 5 NTU	Once per week using grab sampling
Treated water iron	Immediately after filtration before entering the Clearwater tank	Not to exceed 0.3 mg/l	Five times per week, twenty-four hours apart using grab sampling
Treated water manganese	Immediately after filtration before entering the Clearwater tank	Not to exceed 0.05 mg/l	Five times per week, twenty-four hours apart using grab sampling

Notes:
Monitoring of these parameters is not required during the calendar days the treatment plant is not operated or during statutory or civic holidays.
Raw and treated water turbidity monitoring are also required from a compliance point of view.
Raw water *Giardia* levels will be based on the running annual average of monthly samples over a two-year period (See Table 1.1)
Raw water flow rates should be reported in m^3/d.
Specified monitoring for iron and manganese is required only for plants treating for these parameters.

2.3.9 Water Treatment Chemicals

2.3.9.1 Labels and Material Safety Data Sheets

Federal and provincial legislation requires hazardous products at worksites to be labeled and information be made available to workers through Material Safety Data Sheets. It also requires employers to train workers and workers to be knowledgeable with the Workplace Hazardous Materials Information System (WHMIS).

Most chemicals used for water treatment are "controlled products". "Controlled products" are hazardous products at the worksite that meet certain criteria, will either be labelled with a supplier label or worksite label, in accordance with the requirements specified in the latest edition of WHMIS.

For appropriate use of the chemical, water treatment operators should be aware of the chemical purity (concentration), shelf life, expiry data, and 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 shall 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.

Storage buildings and outside storage tanks should be labelled or placarded with the name of the product and/or hazards of the products.

2.3.9.2 Storage and Handling

1. General Provisions

   Storage should be provided for at least thirty days of consumption at the maximum anticipated chemical usage rate, allowing for variations in chemical dosage and flow in that period. Alternatively, the systems should have a program in place to ensure unlimited supply of those chemicals. Storage capacity for essential chemicals should be at least sixty days, with ninety days preferred. Where deliveries of chemicals may be interrupted by adverse weather conditions in isolated locations, provision should be made for increased storage capacity taking into consideration that some chemicals degrade with time, e.g. NaOCl. Where deliveries at short notice can be assured and the material is not essential to the production of safe water, then requirements may be reduced. If practical, there should also be sufficient storage space to accommodate 'full load' deliveries.

   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, e.g. chlorine, fluoride and ammonia or strong acids and alkalis, 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.

It is strongly recommended that all chemical storage be at or above the surrounding grade. Where subsurface locations for chemical storage tanks are proposed, these locations should be free from sources of possible contamination, having drainage for ground waters, chemical spills, and overflows. Where above grade storage is provided, due consideration should be given to the method of unloading chemicals. In general, storage areas should be arranged to prevent any chemical spills. Floor surfaces should be smooth and impervious, slip-proof, and sloped so as to drain rapidly; walls and floors should be protected with a chemical-resistant finish. 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. It is recommended that all doors in chemical buildings open outward, and that corridors or space between storage areas be a minimum of 1.5 m wide to permit the safe movement of materials.

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. Where large amounts of dust are anticipated, appropriate local exhaust systems and filters or scrubbers should be provided in the ventilation system. Ventilation systems should be designed specifically for corrosive service, and special measures taken in dust systems to prevent build-up of static or other explosive conditions.

2. Liquid Chemicals

All bulk storage tanks should have an adequately sized fill line, sloped to drain into the tank. The fill line should be adequately identified at the end that is remote from the tank, and provision should be made to drain this fill line if required.

Each tank should have an adequate vent line, with a down-turned end. Where venting outside the room is required, the vent should be provided with an insect screen.

All tanks should have an overflow which is adequate for the rate of fill proposed for the tank, sloped down from the tank with a down turned end with free discharge located where it can be readily noticed. Overflow shall not be directly discharged into storm drainage system or to a watercourse. If discharged into the sanitary sewer system, the overflow pipes shall not connect directly to the sewer, and where they pass into a receiving sump or conduit they shall terminate at least two pipe diameters above the maximum level in the sump. Each tank should also be provided with means to indicate the level of contents in the tank, and where an external level gauge is provided a shut-off valve at the tank connection is recommended.

All storage tanks should also be surrounded by a structure to contain the volume of the largest tank in the event of a rupture or spill.

In small treatment plants, day-tanks should be provided for the liquid chemicals. Flow meters should be provided for all liquid chemical systems without day tanks.

3. Dry Chemicals

Where dry chemicals are to be used, provision should be made to minimize handling and dust problems. From a materials handling perspective, granular materials should be preferred to powders.

Particular care should be taken to protect workers and mechanical and electrical equipment from fine dust. Where exhaust fans, filters, and conveying systems are used, grounding should be provided to prevent the build-up of static electricity. Dust control equipment should also be protected against moisture accumulation.

Bulk storage silos should be provided with adequately sized fill openings, and fill lines where necessary should be smooth internally with long radius elbows. Silos should have suitable level indicating devices and shall be equipped with a pressure relief valve when pneumatic fill systems are provided.

If powdered activated carbon (PAC) is used, spark-free lighting and electrical systems should be provided. Provision shall also be made to scrub or filter the carrier air, when dry PAC is off-loaded into silos.

4. Hypochlorite Solution

Municipalities should purchase hypochlorite solution with low levels of chlorate. Steps should be taken to avoid formation of chlorate ions in the solution. Hypochlorite solutions should:

- contain less than 1500 mg chlorate/L;
- have a pH greater than 12;
- be used within a relatively short time frame after delivery (within 3 months);
- be stored in a cool dry location where the temperature does not exceed 30°C, away from sunlight; and
- contain less than 0.08 mg/L of transition metals.

Manufacturers are able to produce bleach that has a lower initial concentration of chlorate; municipalities should specify hypochlorite solutions with a chlorate concentration as low as possible to ensure that they will meet the Canadian drinking water quality guideline.

2.4 Water Transmission and Distribution Mains

Where local municipal standards and guidelines for transmission and distribution mains exist, then those standards and guidelines may be followed.

2.4.1 Pipe Sizing

Water mains designed to carry fire flows should have a minimum inside diameter of 150 mm. For smaller distribution systems without fire flow provision, hydraulic calculations should verify that the proposed pipe sizes are sufficient to sustain the minimum operating pressure as defined in Section 2.1.4.

2.4.2 Valves and Hydrants

2.4.2.1 Valve Placement

Water distribution systems should have shut-off valves located to allow any pipeline to be isolated for repairs.

Air release valves should be placed at all significant high points in the transmission system, and should also be considered at high points in the water distribution system. In addition, drain valves should be placed at low points of large mains to permit drainage during repairs to the distribution system.

2.4.2.2 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 the most current Fire Underwriters Survey publication entitled Water Supply for Public Fire Protection - A Guide to Recommended Practice.

2.4.3 Pumping

In general, the requirements for treated water pumping station are similar to those outlined in Section 2.2.4.3 for raw water pumping station.

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 not less than 150 kPa.

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 or diesel 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 in compliance with the security assessment plan.

2.5 Potable Water Storage

2.5.1 Sizing

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 + (the greater of C or 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, as detailed in 1.10.3.7.

The level of fire protection is the responsibility of the municipality. 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.

The designer should recognize that the given formula for calculating treated water storage requirements shall be supplemented with the storage required for the operation of the water treatment facility, i.e. filter backwash and domestic use.

2.5.2 Phasing

Treated water storage requirements should be calculated using a first phase projected demand of no more than 10 years (refer to Section 2.1.2). Present worth cost analysis may show that longer design periods are more economical, however the failure to properly phase the storage requirements can result in operational problems due to oversized pumping facilities and/or problems with maintaining the required chlorine residual if the available storage is excessive.

2.5.3 Alternative Types

There are many alternative methods for the provision of treated water storage at either the water treatment plant or in the water distribution system. The choice of underground, ground level, or elevated storage will depend on factors such as the service area size, topography, and economics. Each alternative should be investigated to choose the best overall method of storage based on specific project conditions.

2.5.4 Site Selection

An economical site selection will depend on the type of reservoir, but in general the major factors to consider are soils conditions, compatibility with future expansion requirements, and site access.

In cases where it may be necessary to provide two-way flow direction during periods of high demand, it is recommended that the storage facility be located on the opposite site of the high demand centre from that at which the supply facilities discharge to the distribution system.

2.5.5 Design Considerations

2.5.5.1 Multi-Cell Provision

Underground or ground level storage reservoirs should be constructed with two cells for ease of maintenance. This can often be accomplished as a result of phasing requirements. Flexibility should be built in to operate the cells in series or parallel; or pump from either cell. When planning the type of reservoir, the designer shall ensure that treated water is not stored or conveyed in a compartment adjacent to untreated water if the two compartments are separated by a single wall.

2.5.5.2 Access

Treated water storage reservoirs should have convenient access to the interior for cleaning and maintenance. Ensure access is secure.

2.5.5.3 Vents

Reservoirs should be vented by specially designed vent structures. On ground level structures, vents should terminate in an inverted 'U' construction, the opening of which is at least 200 mm above the roof or sod, having a cover using suitable non-corrodible screen cloth. Design or enclose vents to prevent the possibility of contaminants being introduced either accidentally or through a malicious act.

2.5.5.4 Drains and Overflows

Where feasible, storage reservoirs should be provided with a drain. There shall be no direct connection between any storage reservoir drain or overflow and a storm or sanitary sewer. Overflows should be located at sufficient elevation to prevent the entrance of surface water. A backflow preventer should be installed on all overflows.

Freezing of overflow lines may result in rising water levels, frozen vents, and collapse of the reservoir by vacuum action. To prevent this occurrence, overflows should be designed with a large inlet weir to allow a substantial flow that is less likely to freeze. It is also desirable to have the overflow discharge to a warm environment.

2.5.5.5 Circulation

It is most desirable to have perfect plug flow through the clear water tank at the water treatment plant. Such a design would ensure that all water entering the tank had the same detention time to ensure a high a T_{10} value (> 0.6). Baffling design and inlet and outlet design can lead to a near plug flow operation. Refer to Appendix 1-D[1] for illustration of typical baffling conditions.

[1] See Standards and Guidelines for Municipal Waterworks, Wastewater and Storm Drainage Systems: Part 1 – Standards for Municipal Waterworks

Balancing reservoirs within the distribution system should be designed to achieve complete mixed flow to avoid poor mixing and circulation, poor turnover rate and excessive detention time.

2.6 Watering Point

Watering point can be either a truck fill station or a barrel fill station.

The truck fill supply should have a minimum pumping capacity of 1000 L/min to minimize the truck fill time; a separate pump should be provided for barrel fill supply. All water supplied from the facility should be metered.

An exterior overhead truck fill arm should be installed. The design shall be such that there will be no cross contamination during or after filling the truck or barrel. If the truck fill is operated in freezing conditions, drain the area to minimize ice build-up due to spillage.

An exterior coin meter activated pump control should be installed so that no person needs to enter the building. The panel should include start and stop buttons, a pump selector switch, and an adjustable maximum run timer or volume control.

2.7 Water Systems Security and Protection

Water systems have been identified as part of the Critical Infrastructure of the province and they must be protected from the threat of terrorism and other forms of criminal behaviour. The following provisions will ensure that water systems operators have accurately assessed the threats to their water systems and introduced appropriate mitigations to ensure continuity of operation and the safety of the public.

2.7.1 Vulnerability Assessment

The waterworks system serving a population greater than 25,000 people should undertake a Security Vulnerability Self Assessment every two years, and systems serving a population less than 25,000 people should undertake the assessment every five years. The system owner / operator should provide certification of performance of the self-assessment submitted to AESRD for review and follow up.

(See Appendix 2-A for details)

2.7.2 Emergency Reaction Plans

The system owner / operator should develop an Emergency Reaction Plan (ERP), it is recommended that the ERP should be developed to the standard set out by The Canadian Standards Institute in CSA z 731. This ERP should be based on the results of the vulnerability assessment and should include response to natural disasters, terrorist acts, and other acts of criminality and system failures.

Emergency Reaction Plans should be reviewed and updated annually to ensure contact information is accurate and the specified resources remain available.

Emergency Reaction Plans should be tested regularly to ensure appropriateness and deliverability. Every test should be documented including any lessons learned and the plan should be updated if required.

2.7.3. Physical Security

The system owner / operator should implement physical protection systems and measures to protect their investment in capital assets and ensure that the safety and security of the public water systems is not compromised by criminal acts.

Physical Protection Systems should incorporate security policies, designs, barriers, devices and systems that offer high degrees of Deterrence, Detection, Delay and Response. These are the basic security principles and can be defined as follows

Deterrence – Make the target unattractive to an adversary by increasing the perception of security. This can be achieved by use of signage, access control and overt uniformed security.

Detection - ensures that if an adversary does decide to attack an asset, that they are detected as early as possible. Detection is achieved by alarm systems, CCTV, Security guards, public and staff.

Delay – Security should incorporate a layered approach with a number of barriers to impede the attacker's progress. Delay is essential to allow for an appropriate response. Layered security is achieved by fencing, locked doors, access control and good design.

Response – Having detected an adversary there should be an appropriate response. In some cases this is achieved by remote assessment using cameras, in other cases this is a response by security guards or plant staff.

2.7.3.1 Personnel

The system owner / operator should consider appointing a Security Manager or other senior manager whose prime responsibility is addressing the security needs of the water utility. This person would be responsible for completion of the vulnerability assessment, implementation of appropriate security measures and delivery of security awareness training. The security manager should be supported by senior management and be adequately resourced.

The system owner / operator should consider initial and periodic background checks on employees and on-site contractors. Appropriate policies should be developed and implemented governing the performance of such screening and the criteria for adverse employment decisions.

2.7.3.2 Training

The system owner / operator should develop and deliver security awareness training to all staff on a regular basis. This training should include awareness on the Emergency Reaction Plans and specific roles and responsibilities contained within the plan.

The aim of security training is to establish a culture of security within the water utility. All staff are responsible for the security of the system and security considerations should be built into all operations. All staff should be aware of the role they play in securing the assets, from ensuring doors are locked, to challenging strangers and reporting or investigating suspicious incidents.

2.7.3.3 Access Control

The system owner / operator should establish some form of access control to its facilities; especially those concerned with water treatment or treated water storage. Access control can take many forms from simple key control to installation of electronic card access systems. The objective of access control is to prevent unauthorised personnel from gaining access to critical assets or components of the water system.

The following are examples of access controls:

- use of non-reproducible high security keys that should be signed in and out on a daily basis. Issuance of master keys should be limited and all keys should be accounted for by an audit on a regular basis.
- use of ID cards to identify all authorized staff and contractors.
- use of Security Guards to validate the credentials of all staff, contractor and other visitors.
- use of electronic card access or biometric systems to gain access to facilities.

2.7.3.4 Perimeter Security

Water treatment facilities should be fenced to exclude the public from the facility and to protect the water system from unlawful intrusion. Establishing a fence also creates a defensible space for the installation of intrusion detection systems and will deter an opportunistic intruder and provide a platform for the detection of a determined intruder.

Fences should be at least seven (7) feet high topped with three strands of barbed wire. Fences should have a minimum of three (3) metres of clear zone on either side to remove anything, which may hide an adversary or assist them in compromising the fence. Fences should be maintained to ensure they have adequate tension and that the fabric is not suffering from corrosion.

Fences should also be considered for raw water sources, wellheads, and treated water storage and distribution components such as pumping stations.

2.7.3.5 Detection Systems

The system owners / operators of water treatment plants and facilities should ensure that intrusion detection systems (alarm systems) are installed to detect an unlawful intruder. Such systems should be monitored by a ULC Certified monitoring company or by the municipalities own security staff.

Consideration should be given to the installation of exterior intrusion detection systems, such as:

- fence line intrusion detection
- exterior passive infra-red sensors

- microwave sensors
- buried magnetic sensitive cable
- digital closed circuit television systems

Consideration should be given to the installation of intrusion detection systems onto treated water storage access hatches.

2.7.4 SCADA Security

The municipalities / system owners / operators should take steps to ensure the availability, confidentiality and integrity of computer systems used to control water treatment, distribution or quality monitoring. Where possible, SCADA systems should not be on the same network as other business or municipal computing systems.

2.7.4.1 Critical Cyber Assets

The system owners / operators should quantify their critical cyber assets, that is the components of their SCADA network, without which the ability to deliver on their mission is compromised.

Critical cyber assets should be protected, physically and logically, from the threat of unauthorised access.

2.7.4.2 Identification of Connections

All network connections on a SCADA system that utilise a routable protocol should be identified. These connections should be configured to prevent unauthorized access.

2.7.4.3 Authentication and Access

All SCADA systems should be configured to require strong authentication of users. This can be achieved through the use of passwords that are changed periodically and require alphanumeric content. Other methods of authentication can be considered including use of tokens or biometric authentication.

Legacy passwords and old user accounts should be deleted.

Users should assign the minimum level of access required for them to do their job. Administrator or super user type access should be highly restricted and should not be the default user level.

2.7.4.4 Anti-Virus

The municipalities / system owners / operators should consider installation of anti-virus applications on SCADA systems which have network connectivity. Anti-virus systems should be kept updated with the most current signature files.

2.7.4.5 Operating Systems

The system owners / operators should ensure that SCADA operating systems are kept up to date with current patches. Operators should consider development of a SCADA test environment to test newly released patches prior to deployment in the SCADA production environment.

2.7.4.6 Network Logging

The municipalities / system owners / operators should install logging services onto their SCADA systems to track activity such as, users log-on, rejected log-on attempts, user log-off, unauthenticated user sessions, system faults and intrusion attempts.

Network intrusion detection systems should also be considered, but only if the resources are available to monitor and react to network incidents.

2.7.5 Excavations and Open Trenches

In order to ensure public safety, Local Authorities responsible for the construction shall secure excavations and open trenches during non-working periods by installing fences/barricades and/or warning lights/signs.

2.7.6 Reservoirs

To guard against trespassing and vandalism, treated water storage reservoirs should be fenced, and entrance gate, access manholes, and valves or vent houses should be locked.

The reservoirs should also have water-tight roofs and hatches, and any openings should have suitable covers to prevent the entrance of birds, animals, insects or dust and be designed or enclosed to prevent the possibility of contaminants being introduced either accidentally or through a malicious act. Consideration should be given to the installation of secondary hatches and intrusion detection systems.

Where a raw water reservoir is located near developed areas or agricultural land, fencing is required to discourage attempts by children to gain entry and to preclude the entrance of domestic animals. Fencing should be located outside the toe of the berm; chain link fence is recommended. Fishing will not be permitted in raw water reservoirs.

2.8 Facility Risk Assessment

The municipalities / system owner /operator may undertake a self-assessment of the facility every two years to establish the risk factor. The self-assessment report should be submitted to AESRD for review and follow-up. Facility assessment is necessary to assure the general public and AESRD that municipalities / system owners/operators are committed to take the required action to reduce any potential risk in providing safe drinking water to the consumer.

System owners / operators may use the criteria tabled below for facility risk assessment.

Table 2.7
Waterworks System Assessment Criteria

Source		Treatment Assessment		Monitoring and Operational Assessment
Surface water	**Groundwater**	**GWUDI**	**Groundwater**	**Surface water and Groundwater**
Quantity - Can the source provide a secure, long-term supply of raw water? If yes, is the raw water storage system adequate? - Have there been trends in supply variability over the past 10 years?	Quantity - Has hydrogeological assessment been done to determine the long-term feasibility of the source? If yes, is the supply adequate? If no, has there been a history of well yield problems over the past 10 years?	Design Criteria - Does the existing treatment process meet current design standards related to the following: - chemical feed and mix - flocculation - clarification - sedimentation - filtration (media, membrane, loading rates, filter-to-waste, backwash, etc.)	Design Criteria - Does the system include components for the treatment of health-related or aesthetic parameters? If yes, does the system meet the treatment standards? - Is the existing system adequate to provide for 4-log reduction of viruses? - Is sufficient disinfection residual provided in the distribution system on a consistent basis?	Monitoring - Does the system provide on-line, continuous monitoring for disinfectant residual (all systems) and turbidity (for surface water supply systems only)? If yes, is there an alarm method to provide the operator with immediate notification if pre-set limits are exceeded?
Quality - Has an assessment of the raw water supply been done to determine cysts/oocysts removal requirements? - Are there persistent raw water quality problems related to organics, colour, parasites, or blue/green algae? - Does the raw water quality fluctuate frequently?	Quality - Has an assessment of the water quality been done? - Is the supply suspected to be under the influence of surface water (GWUDI)? - Are there health-related parameters for which treatment is required? - Are there aesthetic parameters for which treatment is required?	Capacity - Does the system produce adequate quantities of treated water to meet maximum daily flow? Will the capacity be fully utilized in the next 10 years?	Capacity - Does the system produce adequate quantities of treated water to meet the standards for maximum daily flow? Will the capacity be fully utilized in the next 10 years?	System Operation - Does the system owner employ the facility certified operator directly, or is an operator provided under contract? - Is there a succession plan in place to ensure continued operation by a certified operator? - Has there been a recent history of the owner having difficulties maintaining a certified operator? - Has the system owner prepared an emergency response plan to deal with emerging problems related to the water source, treatment, or distribution system?

Table 2.8
Waterworks System Risk Factor
Source Assessment Summary

Source	1 (minimum risk)	2	Ranking Criteria 3	4	5 (high risk)	Assigned Rank
Quantity	Assessment done. Adequate for present and future needs	No assessment done. Appears to be adequate for present needs	Assessment done. Adequate for present needs but not for future needs	No Assessment done. Appears inadequate for present needs	Assessment done. Inadequate for present and future needs	
Quality	Water quality assessment done, no problems confirmed	Water quality assessment done, no apparent problems	No water quality assessment done, no apparent problems	No water quality assessment done, problems evident	Water quality assessment done, confirmed problems	
Source Protection	Assessment done, no mitigative measures needed	Assessment done, but action taken to mitigate issues	No assessment done, no apparent concerns	No assessment done, problems evident but no action taken	Assessment done, problem confirmed, no action taken to alleviate problems identified	
Overall Rank						

Table 2.9
Treatment Assessment Summary

Treatment	1 (minimum risk)	2	Ranking Criteria 3	4	5 (high risk)	Assigned Rank
Design criteria	The plant meets the design standards	Rating not used	Rating not used	Rating not used	One or more critical component not meeting design standards	
Capacity	Evaluation done. The plant operates within design capacity at present and for future needs	Evaluation done. The plant operates within design capacity at present, but would not meet future needs.	No evaluation done, no immediate concerns	Evaluation done, intermittent, shortages identified, nearly at 90% capacity	Evaluation done, plant has exceeded capacity, persistent shortages at present	
Performance - Filtration (Surface & GWUDI)	Individual filter turbidity < 0.1 NTU at all times	Individual filter turbidity < 0.3 NTU at all times	Combined filter turbidity < 0.3 NTU at all times	Combined filter turbidity < 0.3 NTU at least 95% of the time	Combined filter turbidity > 0.3 NTU more than 5% of the time	
Performance - Fe & Mn removal (Groundwater)	Meets 0.05 mg/L manganese & 0.3 mg/L iron	Rating not used	Meets only one parameter (iron or manganese)	Rating not used	Does not meet 0.05 mg./L manganese & 0.3 mg/L iron	
Performance - Disinfection + filtration: meets 3-log cysts, 3-log oocysts and 4-log virus reduction (Surface & GWUDI)	Meets the prescribed CT / IT requirement, and meets THM standard	Rating not used	Meets CT requirement but not the THM standards	Meets the THM standards but not the CT requirement	Does not meet CT or THM standards	
Performance – Disinfection: meets 4-log reduction virus reduction (Groundwater)	Meets the prescribed CT / IT requirement, and meets THM standard	Rating not used	Meets CT requirement but not the THM standards	Meets the THM standards but not the CT requirement	Does not meet CT or THM standards	
Overall Rank						

Table 2.10
Monitoring and Operation Assessment Summary

Operations Management	1 (minimum risk)	2	Ranking Criteria 3	4	5 (high risk)	Assigned Rank
Monitoring turbidity	On-line, individual filter and combined filter	Rating not used	Online combined filter only	Rating not used	Grab, combined filter only	
Monitoring Disinfection (at point where CT is estimated)	Continuous on-line	Rating not used	Grab daily	Rating not used	Grab less than daily	
Operations (Facility)	Certified operator at appropriate level, cover off, succession plan available	Rating not used	Certified operated at appropriate level, no cover off, no succession plan available	Rating not used	No certified operator at appropriate level, no cover off, no succession plan available	
Operations (SOP/ERP)	SOP/ERP in place	Rating not used	Either SOP or ERP in place but not both	Rating not used	SOP/ERP not available	
Overall Rank						

2.9 Conservation and Reclamation

The system owner / operator shall ensure that the requirements outlined in the AESRD documents *Reclamation Assessment Criteria for Pipelines*, 2001 Draft (Alberta Pipeline Environmental Steering Committee, 2001), as amended, as well as the *Reclamation Criteria for Wellsites, Batteries and Associated Facilities – 1995 Update*, as amended, are met.

Achieving pipeline reclamation success requires an understanding, and the sound management of topographic, soil and vegetation characteristics. Equivalent land capability, based on a comparison of pre-activity (pre-disturbance or control data) versus reclaimed land capabilities on that right-of-way, is considered the standard at which a pipeline operator has met the requisite land surface conditions. Other non-land conditions may also apply. Equivalent land capability is defined as "the ability of the land to support various land uses after conservation and reclamation that are similar to those existing prior to an activity being conducted on the land, but that the individual land uses will not necessarily be identical". System owner / operator shall contact the Regional Director and the landowner and obtain information regarding appropriate land capabilities, subsequent land uses and revegetation strategies.

The three primary land components requiring reclamation management (topography, soil and vegetation) generally co-vary such that changes in vegetation growth patterns, health and population structure are often attributable to changes in soil and topographic characteristics.

TOPOGRAPHY

Surface contour and drainage re-establishment along the pipeline alignment shall be reclaimed to be comparable to pre-disturbance land conditions.

SOIL

Soil Salvage and Handling

Topsoil, upper subsoil and spoil shall be salvaged and stockpiled separately, unless otherwise authorized. Two-lift soil handling can provide a means to salvage upper subsoil and spoil together, provided no "problem" soils (e.g., saline, sodic, rocky) are encountered. When conditions permit the use of overstripping soil handling procedures, all salvaged topsoil admixed with upper subsoil shall be stored separately from spoil.

Topsoil and upper subsoil salvage operations shall be suspended when wet or frozen field conditions, wind velocities, or any other field condition or pipeline construction method may result in soil quality degradation or loss. Operations shall only recommence when those conditions no longer exist. Refer to *DRAFT AENV Manual on Soil Conservation and Pipeline Construction* (1995), as amended, for further guidance.

Soil Storage

Topsoil, upper subsoil and spoil are required to be stockpiled separately. When two-lift soil handling procedures are used, upper subsoil and spoil may be stockpiled together. When conditions permit the use of overstripping soil handling procedures, all salvaged topsoil admixed with upper subsoil shall be stored separately from spoil.

All stockpiles shall be stabilized to prevent wind and water erosion, and constructed with stable foundations.

Soil Replacement

The system owner / operator shall make every effort to progressively reclaim the pipeline alignment when construction is completed, unless the timing of clean up and reclamation have been scheduled to accommodate changes in soil conditions (e.g., frozen).

Salvaged spoil are required to be replaced in the trench and contoured appropriately such that all upper subsoil is spread evenly over the replaced spoil, and that all topsoil shall be spread evenly and contoured over the replaced upper subsoil or spoil.

Topsoil and upper subsoil replacement operations shall be suspended when wet or frozen field conditions, wind velocities, or any other field condition or pipeline construction method will result in the degradation or loss of soil quality. Operations shall only recommence when those conditions no longer exist.

Upper subsoil and spoil compaction shall be alleviated through mechanically breaking, fracturing or shattering prior to topsoil replacement. The approval holder shall also alleviate replaced topsoil compaction in a manner controlled to avoid topsoil mixing with upper subsoil or spoil. Refer to *DRAFT AENV Manual on Soil Conservation and Pipeline Construction* (1995), as amended, for further guidance.

The size and density of coarse fragments (i.e. gravel, rock or stones) within the reclaimed soil profile and on the reclaimed pipeline alignment surface shall be comparable with the adjacent undisturbed land. In forested areas, rollback shall be placed for access management and erosion control.

All works, buildings, structures, facilities, equipment, apparatus or machinery used during construction or reclamation that will not be used for the operation of the pipeline shall be dismantled and removed. All constructed access roads for the pipeline alignment that are not remaining as surface improvements or as a designated property access shall be reclaimed.

VEGETATION

The pipeline alignment shall be stabilized; surface contoured and revegetated using a suitable seed mixture. An effective weed control program shall be in place until new vegetation on the pipeline alignment is re-established and is self-sustaining.

Where the pipeline alignment crosses native prairie areas, native seed mixtures and revegetation practices compatible with those outlined in the document *A Guide for Minimizing the Impact of Pipeline Construction On the Native Prairie Ecosystem* (Alberta Environment, and Alberta Sustainable Resource Development, 2003), as amended, shall be used. Material handling and storage times in aid of native species regeneration are advised. Pipelines shall be constructed in a manner such that the surface disturbance on native prairie, and the degradation or loss of adjacent, undisturbed native prairie is minimized.

APPENDIX 2-A

Security Self-Assessment Guide For Owners and Operators of Alberta Drinking Water Systems

Security Self-Assessment Guide For Owners and Operators of Alberta Drinking Water Systems

Introduction

Water systems are critical to every community. Protection of public water systems should be a high priority for local officials and water systems owners and operators to ensure an uninterrupted water supply, which is essential for public health and safety.

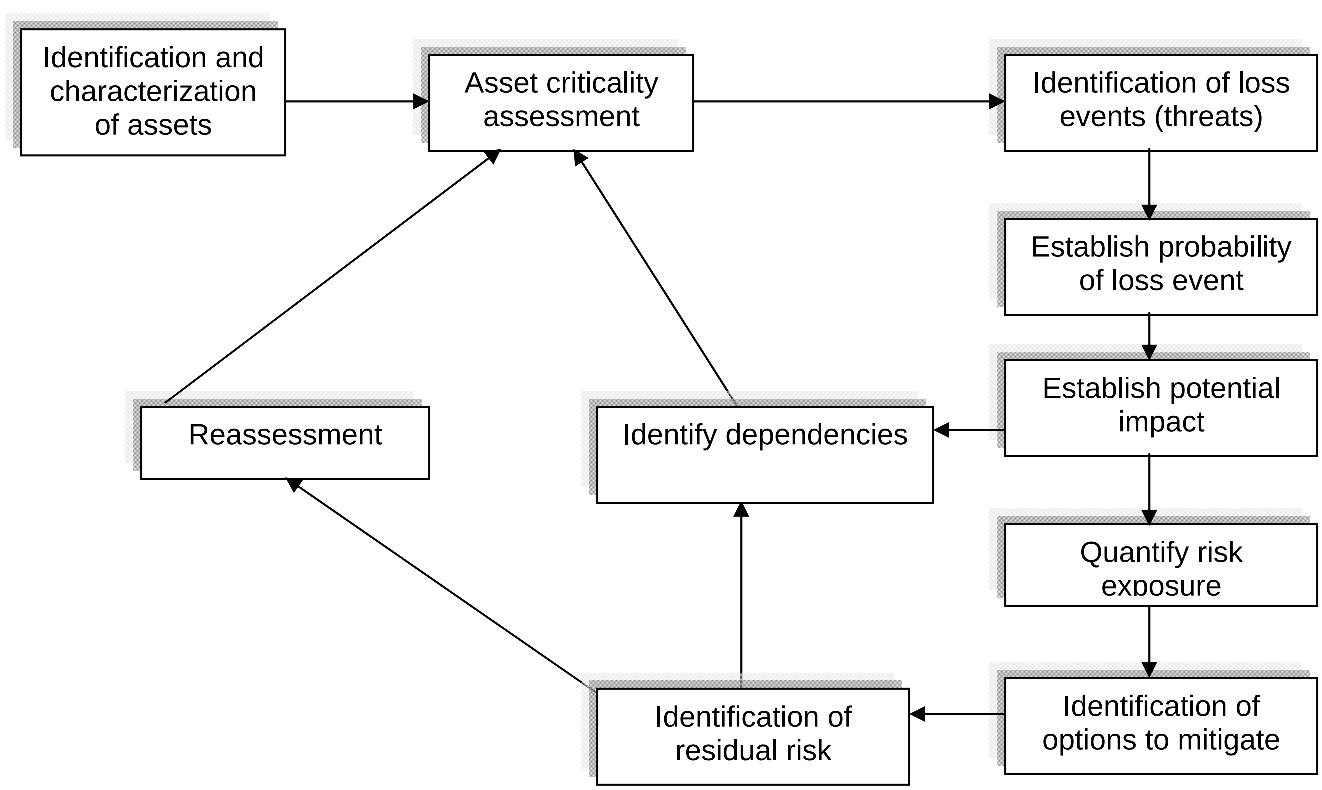
Adequate security measures will help to prevent loss through criminal behaviour including acts of terrorism and every-day vandalism. Proper planning will not only help to prevent such incidents but will mitigate their impact and assist in rapid recovery.

This security self-assessment guide is designed to help water systems determine possible vulnerable components and identify security measures that should be considered in order to protect the system and the customers it serves.

How to use this self-assessment guide

This document is designed for use by water system personnel when performing vulnerability assessments. Assessments should include, but not be limited to a review of physical facilities, distribution systems, treatment facilities, physical barriers, water collection, water storage, computer networks, chemical storage and handling procedures and operational methods. In other words the scope of this vulnerability assessment should be to review the security of the total water system from source to tap.

The self-assessment has a number of steps as shown on this process overview:



a. <u>Identification and characterization of assets</u>

A complete list of all the assets of the total water system should be drafted together with description of these assets and their contribution to the water system (Addendum 2).

b. <u>Assets criticality assessment</u>

All critical assets or water system components should be identified. A critical asset is an asset that, if destroyed or lost would prevent the water system from delivering safe clean water in sufficient quantity or at sufficient pressure.

Additional factors which should be considered when assessing criticality of an assets or components are:

- Interdependency with critical infrastructure or services, e.g. hospitals, power facilities, major customers
- Single points of failure
- Availability of redundant back ups
- Replacement time of components or assets
- Potential for loss of public confidence.

c. <u>Identification of loss events (threats)</u>

This could be as simple as a list of potential threats that a water system might face, or it could be specific to a particular system or geographic location. Common threats to be considered are:

- Vandalism
- Unlawful trespass
- Computer hacking
- Disgruntled employee
- Criminal contamination
- Accidental contamination
- Labour dispute

d. <u>Establish Probability of loss event</u>

The probability that a threat could occur should be quantified. Individual water systems will decide how probability should be quantified however a rating of High, Medium or Low probability could be used. When assessing probability a number of factors should be considered;

- Relevant history of similar events
- The crime rate in each area

- Major changes in socio-economic or demographic situation
- Intelligence of threats from other agencies

It is recognized that although some objective input on probability may be received from sources such as Alberta Environment and Sustainable Resource Development, the Police or RCMP, assessment of probability remains largely subjective. The following table could be used as a means to express probability.

1 **Unlikely**	**2** **Moderate**	**3** **Likely**	**4** **Almost Certain**
3% to 15%	15% to 50%	50% to 70%	> 70%
Small likelihood but could well happen	Less than 50-50 chance	More than 50-50 chance	Almost certain that it will happen, very frequent occurrence
Once in 50 years	Once in 20 years	Once in 10 years	Once per year or more
Low level of threat	Medium level of threat	High level of threat	Imminent threat of attack

e. <u>Establish potential impact</u>

The impact of each loss event should be considered in detail and not just in terms of the ability to affect water quality. For example introduction of a small amount of a chemical contaminant into a treat water storage reservoir would have little or no impact on water quality; however this could have serious impact upon public confidence in the water system.

When considering impact, considerable time must be spent on identification of dependant infrastructure and critical customers. If we were to decide that that a loss of supply to < 500 customers was a moderate impact, but one of those customers was the only hospital in a region, then the impact of that loss event should be considered to have a much higher impact, especially if sustained for a long period of time.

The following table could be used to assist when assessing potential impact. System operators will need to develop their own descriptions and thresholds for what they consider to be Minor, Moderate, Major and Catastrophic events.

	1 Minor	2 Moderate	3 Major	4 Catastrophic
Health and Safety of Employees and Public				
Total Financial Loss				
Loss of Treatment				
Loss of Pressure				
Loss of Supply				
Environmental Impact				
Reputation Impact				
Public Confidence				
Political Impact				
Loss of Control Ability				

f. Quantify Risk Exposure

Risk can be considered to be the product of Probability x Impact. By using the table below we can assess the risk exposure for each identified threat.

For Example: The incidence of graffiti is very high in some areas. If we considered this as a threat or loss event then we would follow the process above which would show that the probability is almost certain, as our crews have to clean this up on a regular basis. When we consider impact we assess that the impact is minor is all of the assessed areas. When we assess the risk using the matrix we find that this is a Medium level of risk that should be managed by introduction of mitigations and procedural security measures.

IMPACT	Catastrophic				
	Major				
	Moderate				
	Minor				
		Unlikely	Moderate	Likely	Almost certain
		PROBABILITY			

	Indicates a Low level of risk - minimal security measures necessary. Risk should be managed through the introduction of mitigation strategies or changes in procedural security, or accepted as a low business risk.
	Indicates a Medium level of risk – Risk should be managed by the introduction of mitigation strategies and high levels of procedural security.
	Indicates a High level of risk – Maximum-security measures should be in place, providing layers of Deterrence, Delay, High probability of detection and rapid effective response. Insurance coverage essential but may not be able to provide adequate coverage to prevent significant liability. Due diligence is required, including utilisation of appropriate expertise and validation of assessed data.
	Indicates a Severe level of risk.- Maximum security measures should be in place, together with recovery plans, mutual aid agreements and availability of critical spares.

g. Identification of countermeasures, their costs and trade-offs.

i. Identify potential security countermeasures to reduce the vulnerabilities.

ii. Estimate the cost of the countermeasures.

iii. Conduct a cost-benefit and trade-off analysis.

iv. Prioritize options and recommendations for senior management.

The results of the Threat and Risk analysis can then be plotted and recorded on the matrix shown at Addendum 3. This form can also be used to show recommended mitigations and ongoing mitigation strategies.

Self-Assessment Worksheet

A self–assessment work sheet is shown at Addendum 4. This guideline will assist operators to ask the right questions when reviewing the security regimes in place at various plants and facilities. The guideline is designed to prompt operators to look at various security aspects and determine a course of action appropriate to their operation. This guideline is not intended to be a security manual or to deliver advice or instruction to operators on the exact security measures to be installed at each facility. Operators should seek specialized security advice from qualified practitioners if they have no internal resources assigned to the security function.

Upon completion of this self-assessment system owners/ operators should complete the certificate shown at Addendum 1 and forward this to Alberta Environment and Sustainable Resource Development.

ADDENDUM 1

Certification of Completion of Security Self Assessment
Drinking Water System

To: Alberta Environment and Sustainable Resource Development

Name of Water System:

Administrative Address of Water System:

I certify that on -----(Date)----- a Security Self-assessment was performed on the above-indicated Drinking Water system. I further certify that the information in this self-assessment has been completed to the best of knowledge and that the appropriate parties have been notified of the assessment and the recommended steps to be taken to enhance the security of the water system. Furthermore a copy of the completed self-assessment will be retained at the administrative offices, in a secure location, and will be available for inspection by Alberta Environment and Sustainable Resource Development as requested.

I further certify that --------(Name)--------- has been delegated with the responsibility for security as it pertains to this water system.

Yours sincerely;

____Signed

________________________DATE

ADDENDUM 2

Component type	Number & Location	Description	Criticality or Single Point of Failure	Comments
Source Water				
Ground Water				
Surface Water				
Other				
Treatment Plant				
Buildings				
Pumps				
Process controls				
Treatment chemical storage				
Laboratory chemicals and storage				
Other				
Storage				
Reservoirs				
Storage tanks				
Pressure tanks				
Other				
Power Supply				
Primary power supply				
Auxiliary power supply				
Other				
Distribution System				
Pumps				
Pressure reducing valves				

ADDENDUM 2

Component type	Number & Location	Description	Criticality or Single Point of Failure	Comments
Pressure sustaining valves				
Other valves				
Hydrants				
Back flow preventers				
Other				
Communications & Control				
SCADA Assets				
- RTU's				
- PLC's				
- IED's				
- Control terminals				
- Servers				
- Switches / firewalls etc.				
Telephony systems				
Cell phone systems				
Radio systems				
Business network systems				
Other				
Administration				
Office buildings				
Computer systems				
File storage				
Service vehicles				
Personnel				
Other				

ADDENDUM 2

Component type	Number & Location	Description	Criticality or Single Point of Failure	Comments
Critical Infrastructure Customers				
Power plants				
Hospitals				
Schools				
Food processing plants				
Major industry				
Other				

ADDENDUM 3

Threat and Risk Assessment							
ASSET	**Water Treatment Plant**					**CRITICALITY**	**HIGH**
Threat or hazard	**Vulnerability**	**Prob.**	**Impact**	**Risk**	**Recommended mitigation(s)**	**Residual risk**	**Ongoing mitigation**
Vandalism (EXAMPLE)	Facilities are not fenced	Moderate	Moderate	MED	Consider installation fencing Install signage	LOW	▪ Staff awareness and vigilance ▪ Maintenance program for fences

ADDENDUM 4

Drinking Water systems Security Self-Assessment worksheet		
Name of Water System		
Number of customers served		
Administrative address		
Security manager name (Or manager with Security Responsibility)		
Telephone number		
Date review completed		
Persons involved in review process		
Date of review of outstanding action items		
Question	**Answer**	**Action Needed / Taken**
Personnel		
Have you appointed a security manager or senior manager with responsibility for security of the water system?		
When hiring personnel do you perform background checks or require criminal record checks?		
Do you have a security awareness training program?		

ADDENDUM 4

Drinking Water systems Security Self-Assessment worksheet		
When terminating employees do you have a defined ‘End of Service’ process, which disables logical and physical access and requires the return of keys, ID cards and other security related items?		
Have water system personnel been advised to report security vulnerability concerns or suspicious behaviour to the Security Manager or department?		
Emergency Reaction Plans		
Do you have a written Emergency Reaction Plan (ERP) which conforms to Canadian Standards Association standard CSA z731?		
Is there someone designated with the responsibility to ensure the ERP is updated and reviewed?		
Has the ERP been tested in the last year?		
Are records kept of all ERP tests? When was the ERP last reviewed and updated?		
Are the contact lists shown in the ERP up to date with correct information?		
Have first responders (Fire, EMS) been made aware of the plan and contributed to its formation or review?		
Do you have a Business Continuity Plan (BCP)?		

ADDENDUM 4

Drinking Water systems Security Self-Assessment worksheet		
When was the BCP last tested, reviewed and updated?		
Who is responsible for the maintenance of the BCP?		
Physical Security		
Is access to critical components of the water systems restricted to authorized personnel only?		
How is access control achieved?		
Are employees and authorized contractors required to carry or display ID badges?		
Do you use non-reproducible keys? If so, how is distribution of these keys achieved? Do you perform regular audits of keys and require that keys be signed in and out?		
Are buildings locked when not in use? Is there a process or control in place to ensure buildings are locked? Are service vehicles locked when not in use? Is critical equipment stored in vehicles?		

ADDENDUM 4

Drinking Water systems Security Self-Assessment worksheet		
Do you use an electronic card access system? Are different levels of access granted to employees and contractors based on the principle of the least amount of access necessary to perform their role? Are access levels routinely audited to ensure currency? What procedures are in place to deal with employees who transfer to other responsibilities?		
Have buildings been designed to incorporate Crime Prevention Through Environmental Design (CPTED) principles? Are new buildings required to incorporate CPTED principles? Are new building plans subject to approval from the security manager or architect with CPTED experience?		
Are critical buildings fenced? Are fences at least 2130 mm high with 3 strands of barbed wire on top to prevent climb over? Are fences subject to regular inspection and maintenance?		

ADDENDUM 4

Drinking Water systems Security Self-Assessment worksheet		
Is a clear zone of 3 metres in place on either side of all fence lines? Are gates properly secured with high security locks, electronic access control or high security padlocks? Is adequate “No Trespass” signage in place beside the main entrance and at all four corners of each facility, as required by the Trespass to Premises Act? Is this signage in good condition and legible? Are there adequate warning signs in place to warn of site dangers? High Voltage, Deep Water, Chemicals etc.?		
Are intrusion detection systems installed? Where and how are these monitored? What is the response to an alarm activation?		
Are reservoir and tank access hatches and vents locked? Are tamper proof hinges and locks used on reservoir and tank access hatches? Are these regularly inspected?		

ADDENDUM 4

Drinking Water systems **Security Self-Assessment worksheet**		
Are any intrusion detection systems installed on reservoir or tank access hatches? Is there a response plan for alarm activations involving reservoir and tank access hatches? Is the area around critical components free of objects which may be used for breaking and entering (e.g. Large rocks, cement blocks, pieces of wood, ladders, valve keys and other tools)?		
Do you have a neighbourhood watch program for you water system?		
Do wellheads, pumps and treatment facilities have back up power supplies? If so, when were these last tested? Is there a preventative maintenance program in place for back up generators? Is there spill containment in place for diesel fuel tanks required by back-up generators?		
Do secured manhole covers or secondary locking devices protect critical valves? Are these inspected on a regular basis?		

ADDENDUM 4

SCADA Security		
Does access to SCADA systems require a user name and a strong password? Are passwords changed on a regular basis? Are controls in place to stop the sharing of passwords? Are separate accounts created for contractor access to SCADA? Are user accounts removed from SCADA upon termination of employees or contracts? Is there a single point of accountability for SCADA systems?		
Have all SCADA connections with the Internet or modems been identified and documented? Are these connections protected by firewalls or other forms of connection that authenticates user sessions?		
Have redundant or obsolete connections been removed or deactivated?		
Are SCADA operating systems properly patched? Is there a process in place to ensure prompt patching of identified vulnerabilities? Are patches tested prior to deployment?		

Are SCADA applications properly patched and upgraded with the latest version? Is there a process in place to ensure SCADA applications are promptly patched and to ensure currency of the latest version?		
IS the SCADA System connected to a business or administration network? Is the SCADA system properly partitioned from the business network?		
Do you have a disaster recovery plan for SCADA systems? Has this plan been tested and reviewed?		
Are details of you water system posted on an Internet site? Have these details been reviewed to ensure that no information is displayed which may be used to compromise the water system?		

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