Water Security Agency

# Waterworks Design Standard

# EPB 501

November 15, 2012

**Foreword**

This document replaces A Guide to Waterworks Design published by Ministry of Environment on January 2008.

This design standard applies to all waterworks described in *The Waterworks and Sewage Works Regulations* and shall be used as a companion to the applicable Acts, Regulations and other provincial publications currently in use or as may be published from time to time. These publications include:

- *The Environmental Management and Protection Act*, *2010*:
- *The Waterworks and Sewage Works Regulations*;
- Guidelines for Canadian Drinking Water Quality
- Saskatchewan Drinking Water Quality Standards and Objectives
- Government of Saskatchewan First Nation and Métis Consultation Policy Framework
- Municipal Drinking Water Quality Monitoring Guidelines
- Cartridge Filter Permitting Guidelines
- Chlorine Dioxide
- Waterworks System Assessment Questions and Answers
- Ozone
- Ammonia in Source Water
- System Depressurization
- Managing Wastes Generated by Water Treatment, Distribution, Maintenance, Repair and Extension
- Guidelines for Chlorine Gas Use in Water and Wastewater Treatment
- Groundwater Under the Direct Influence of Surface Water Assessment Guideline
- Use of Chemicals in Drinking Water Treatment
- A Guide to Aquatic Nuisances and Their Control
- Terms of Reference Preparation Guide for Water and Wastewater Work Studies
- Security at Water Treatment Plants
- Wellhead Protection
- Water Pipeline Design Guidelines
- Cross Connection Control and Backflow Prevention Program Guidelines

The design of a waterworks shall:
- identify all items and factors that need be considered for the construction, operation and maintenance of a waterworks; and
- provide accepted practices suitable for Saskatchewan conditions.

This standard is not intended to be a detailed engineering manual. Innovative or alternate approaches with demonstrated benefits are encouraged and need to be approved by the Water Security Agency and then utilized to protect both public health and the environment.

Please forward inquiries concerning the standards and guidelines to:

Environmental and Municipal Management Services Division
Water Security Agency
420-2365 Albert Street
Regina, Saskatchewan
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Phone: (306) 787-0726
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# 1. Information Submissions for Approvals

## 1.1 Approval Requirements

An approval to construct, extend or alter any waterworks must be obtained from the Water Security Agency before starting construction of such works. The requirement for an approval to construct is seen in Section 24 of *The Environmental Management and Protection Act*, *2010*. Applications for approval are required to be made on prescribed forms.

Typical examples of works requiring construction approvals include:

- water treatment facilities including surface water, groundwater and GUDI plants;
- water distribution systems and extensions at systems serving fewer than 5000 people; and
- water pumping stations;

Applications for approvals are required to contain information prescribed in section 1.2. Information shall be in a concise form and a logical order. Drawings and plans shall conform to good engineering practice. Previously submitted information need not be resubmitted unless it is affected by the construction, extension or alteration or updating is appropriate.

## 1.2 Information on Application for Permit

### 1.2.1 General

When a person makes an application for a permit, he/she shall include in the application:

- engineering reports for new systems and major modifications;
- name(s) of owners and responsible party for operation and maintenance;
- designer or responsible engineer or engineering firm;
- proposed period of construction and anticipated operation date;
- cost estimates for the work including applicable local improvement or capital portions;
- where new water distribution piping or a new volume load on the water treatment plant is proposed, provide a statement that the water pumping, treatment and existing waterworks are adequately sized to meet all requirements including meeting all required MAC quality limits OR provide a statement indicating how pumping, treatment and existing works will be upgraded or mitigated in a manner previously negotiated with and agreed to by the Water Security Agency;
- proposed security features at the works (refer to publication Security at Water Treatment Plants); and
- if applicable, application for permit shall include easement agreement containing the following information and provisions:
  a) the name of the person proposing to construct, extend, alter or operate the waterworks that is the subject of the easement;
  b) the nature and extent of the construction, extension, alteration or operation of the waterworks that is the subject of the easement;
  c) the name of the registered owner of the land on which the waterworks that is the subject of the easement is to be constructed, extended, altered or operated and, if different, the name of the registered owner of the land affected by the waterworks that is the subject of the easement;
  d) the legal description of the lands mentioned in clause (c); and
  e) a provision that:
     i. grants an easement by the registered owners of the lands affected by the waterworks that is the subject of the easement;
     ii. conveys a right to use the land for the purposes and to the extent required to construct, alter, extend or operate the waterworks that is the subject of the easement; and
     iii. states that the easement runs with the land and is binding on the present and subsequent registered owners of the lands affected by waterworks that is the subject of the easement and their heirs, executors, administrators and assigns.

### 1.2.2 Water Supply Changes

An Alteration in water source is defined as a change away from the existing surface water class or groundwater class or GUDI source class; for example changing from a groundwater class to a surface water class source. An application for permit to construct is required with the following information;

- site plan showing source location, other relevant features, and means of access;
- as seen in Section 28 of The Waterworks and Sewage Works Regulations, written confirmation that the drinking water from this Altered source, once treated, shall meet;

    - the standards set out in Table 3 in the Appendix and the standards set out in the permittee's permit (if available from permit at time of design);
    - the standards for microbiological characteristics specified in section 29,; and
    - the turbidity, protozoan and viral standards specified in section 30 of The Waterworks and Sewage Works Regulations.
- description of relevant local activities, uses or other factors that may impact on the water quality;
- description of ability of proposed works to meet Aesthetic water quality parameters;
- description showing that CT requirements shall be met;
- drawings and specifications showing structural, piping, and equipment details for pump houses together with description of capacities, etc;
- plan and profile of the water supply main indicating the size, material, location, depth and appurtenances;
- for groundwater supplies, the depth, diameter, screen details and the rated capacity of the well together with the type and capacity of the pumps; and
- for surface water supplies, details of impoundments, intake works, the type and capacity of pumps, hydrological projections, intake operating mode and planned or contemplated source treatment.

An Adjustment in water source is defined as a new intake into a similar source class; for example drilling a new well to replace a failed well in the same aquifer or constructing a new river intake to replace an old river intake in the same river. An application for permit to construct is not required; however, other permits may be required. Written notification to the Environment Officer and the Drinking Water and Wastewater Management Division of the Water Security Agency is required with the following information;

- site plan showing source location;
- description of ability of proposed works to meet Aesthetic water quality parameters;
- description showing that CT requirements shall be met;
- as seen in Section 28 of The Waterworks and Sewage Works Regulations, written confirmation that the drinking water from this Adjusted source, once treated, shall meet;
    - the standards set out in Table 3 in the Appendix and the standards set out in the permittee's permit (if available from permit at time of design);
    - the standards for microbiological characteristics specified in section 29,; and
    - the turbidity, protozoan and viral standards specified in section 30 of The Waterworks and Sewage Works Regulations.

**1.2.3 Water Treatment**

- procedures and results of treatability studies;
- site plan showing location of treatment facilities, wastewater discharge system and means of access;
- calculations used to determine the size and capacity of treatment units and the equipment;
- process flow diagram including optional treatment procedures, hydraulic flow diagram and monitoring features;
- the principles of treatment and capacities of individual treatment units of the proposed water treatment facility;
- drawings and specifications giving the structural, piping and equipment details;
- as seen in Section 28 of The Waterworks and Sewage Works Regulations, written confirmation that the drinking water, once treated, shall meet;
    - the standards set out in Table 3 in the Appendix and the standards set out in the permittee's permit (if available from permit at time of design);
    - the standards for microbiological characteristics specified in section 29,; and
    - the turbidity, protozoan and viral standards specified in section 30 of The Waterworks and Sewage Works Regulations.
- description of ability of proposed works to meet Aesthetic water quality parameters;
- description showing that CT requirements shall be met;
- description or listing of laboratory and safety equipment; and
- description of proposed plant operational modes and the required operational capability.

**1.2.4 Water Storage**

- site plan showing location of reservoir, waste discharge system and connections;
- drawings and specifications giving the structural, piping and equipment details; and
- description of the capacity and mode of operation.

### 1.2.5 Distribution

- plan of the distribution system showing the location of the pipe in the street in relation to other underground utilities, the depth of pipe burial, profile elevations, the type and size of pipe, and location of hydrants, valves and appurtenances;
- description of the water main location using street referencing where possible; and
- design information for the distribution or water transmission system including flow capacity, areas served and future areas to be served.

### 1.2.6 Heritage Resource Review

All projects with an areal impact outside a high-density or built-up area will need to undertake a Heritage Resource Review (HRR). This will assist in determining if a broader Heritage Resource Impact Assessment (HRIA) or further assessment is necessary. Areal impact is an impact over an area that potentially has heritage issues (i.e. a new subdivision proposed on the outskirts of a village requires an HRR but a new large watermain or sewer main on an existing developed street does not require a HRR.) HRRs must be performed as early in the project as possible. If a proponent requires a ruling on whether a water and sewer project needs an HRR, please contact an Approvals Engineer. Heritage and similar evaluations as required by other agencies must be performed. If your project needs a HRR, please complete and forward the *Heritage Resource Review Referral Form – Water and Sewer Works Form* found under the heading *Water and Sewage projects* available on the internet (http://www.tpcs.gov.sk.ca/HeritageReviewForms) along with a basic site plan asking for a review and asking to determine if an HRIA is necessary to the Archaeological Resource Management, Ministry of Parks, Culture and Sport, 9th Floor 1919 Saskatchewan Drive, Saskatchewan, S4P 4H2. Fax (306) 787-0069 or Telephone (306) 787-8157 / 787-5774 / 787-2848 / 787-5753.

### 1.2.7 Consultation

Consultation must take place before any project or other activity that could adversely affect Treaty or Aboriginal rights is developed or put in place. The proponent must start the Consultation as early in the project development process as possible; suitable time must be allotted if a Consultation is needed. To determine whether a proposal needs a Consultation with First Nations and Métis People and to determine the content and scope and scale of the Consultation, contact an Approvals Engineer. In some proposals Consultation has been completed or is being undertaken with another agency before the Water Security Agency is involved. Further information is available in the publication *Government of Saskatchewan First Nation and Métis Consultation Policy Framework*, June 2010 which is online at; http://www.fnmr.gov.sk.ca/adx/aspx/adxGetMedia.aspx?DocID=451f49fa-038c-4591-b02d-468da3ac8635&MediaID=987&Filename=CPF-final.pdf&l=English

## 1.3 Installation of New Waterworks Treatment Technology in Saskatchewan

The Water Security Agency encourages municipalities, systems owners and other interested parties to look for innovative ways to meet water and wastewater standards and minimize the risks to the environment and public health.

Two options are available to owners and designers when evaluating water and wastewater projects involving new or un-proven treatment technologies:

### 1.3.1 Approval by Regulatory History

To approve a treatment technology that is new to Saskatchewan, the Water Security Agency requires proponents to submit a proof and details that the new treatment technology has a track record of approval by other regulatory agencies and a history of successful installation and operation, including but not limited to technical performance and operation under climatic conditions similar to Saskatchewan. Further, the proponents must submit a statement stamped by an experienced professional engineer that the new treatment technology meets all Water Security Agency standards, guidelines or requirements for performance and quality as a means to protect public health and the environment.

### 1.3.2 Approval by Verification or Certification

The second option for approving a treatment technology new to Saskatchewan is for the proponent to obtain Verification or Certification by a third-party Evaluation Agency. The Evaluation Agency could be Environmental Technology Verification Program (ETV) or National Sanitation Foundation (NSF) or a similar agency. The Water Security Agency does not endorse any specific testing agency. The Water Security

Agency must be involved with design of the approval work under the verification or certification. Approval requires a statement stamped by an experienced professional engineer that the new treatment technology meets all of Water Security Agency's standards, guidelines or requirements for performance and quality as a means to protect public health and the environment. Contact Senior Standards Engineer or Approvals Engineer for further information.

### 1.4 Pilot Plants

Pilot plants or small-scale plants are commonly used to demonstrate new treatment technology or for application of a specific technology at a site. Until the full performance of pilot plants can be assured, installation at water or wastewater treatment facilities may represent a threat to health or environmental quality, therefore it is important that pilot plants are not installed before approval by the Water Security Agency. Pilot plants at facilities regulated by the Water Security Agency require an application for a permit to construct. For pilot plant studies, all technical information must be submitted along with the application and stamped by a Professional Engineer with significant municipal experience. The application also must include a statement that the new treatment technology do not have adverse effects or impacts on t public health and environmental quality.

### 1.5 Innovative Systems and Planning for Growth

The Water Security Agency encourages municipalities, system owners and other interested parties to look for innovative and reliable ways to meet drinking water and wastewater standards established to minimize risks to the environment and public health.

To maximize the potential for success of innovative water systems, owners and designers of innovative systems are recommended to consider the following regarding innovative systems, planning for growth, and cost studies;

- obtain opinions from a non-biased expert source;
- the risk of community dissatisfaction with new water infrastructure is higher where a treatment technology or similar technology is selected and built based solely on the advice of treatment equipment suppliers;
- an equipment supplier wishes to sell their brand of equipment, and this equipment may not be the best option for the community in practical or financial terms in either the short or long term;
- when selecting a water treatment or similar technology, decision makers are advised to *obtain a third-party non-biased engineering consultant to review several treatment options and recommend the best option;*
- the Water Security Agency may not approve expansion such as new subdivisions if that new growth places an unacceptable load on water infrastructure;
- incomplete planning at the earliest stages can result in owners investing money in detailed design of new growth such as subdivisions only to have that growth and investment return stopped later due to insufficient water infrastructure;
- owners are advised to have an expert determine if their water and sewage infrastructure can support proposed new growth early in the planning stages;
- at the planning stage, owners should base cost comparisons not just on initial capital build cost, but should compare different options on a Life Cycle Cost which allows for comparison of initial build cost and annual operating cost for different options;
- a non-biased expert should be consulted to select the best water infrastructure options for construction, and part of that selection study needs to be a Life Cycle Cost comparison of different treatment and infrastructure options.

### 1.6 Terms of Reference

When a water and wastewater works encounters infrastructure or operational based problems with their system or the owner wants to assess the condition or suitability of their works, an Engineering Investigation is often required. In order to properly identify the components and terms of the Engineering Investigation a Terms of Reference (TOR) should be created by the water or wastewater works owner. Creation of a TOR allows the proponent to identify the requirements of the study and can help the consultant ensure that the study result fulfills these requirements.

The publication Terms of Reference Preparation Guide for Water and Wastewater Work Studies is provided to water and wastewater works in order to aid in voluntarily creating their own TOR. When using this document it is important to keep in mind that it only provides a general framework. Therefore, when creating a TOR, it is essential to tailor the TOR to the specific situation at hand. In addition, creation of a TOR should be made in consultation with the Water Security Agency to help ensure the TOR identifies the proper issues. For more information please see publication Terms of Reference Preparation Guide for Water and Wastewater Work Studies.

## 2. Water Supply

### 2.1 General

#### 2.1.1 Approvals

During the investigation for water supplies, the requirements of other administrative authorities with respect to water rights, groundwater exploration, environmental impact assessments, planning, and intake siting, etc., need to be reviewed and applicable consultation undertaken. Required approvals from other authorities must be obtained.

#### 2.1.2 Characteristics

The water supply shall be of such quality so that the municipal drinking water quality objectives can be achieved with appropriate treatment technology. Quality considerations include potential future changes and other variables that may impact on treatment capability or water safety. The capacity of the supply shall provide confidence in the long-term expectations for the source.

#### 2.1.3 Multiple Supplies

Where multiple supply sources are desired due to water quantity or quality factors, consideration need to be given to optimizing water quality and minimizing variability. If feasible, water from different sources may need to be blended prior to distribution. Considerations for the provision of standby or emergency supplies shall include:

- primary source reliability and risk for potential problems;
- storage capacities with respect to demands;
- anticipated maintenance and repair schedules; and
- alternate supply options.

#### 2.1.4 Purchased Supplies

Waterworks using water supplies provided by others shall carefully consider:

- a long-term agreement;
- water quality;
- water delivery rates and reliability of delivery; and
- responsibilities of the supplier and user. Waterworks obtaining treated water provided by others need to have disinfection capabilities and records of supplied water quality.

### 2.2 Surface Water

#### 2.2.1 Capacities

Storage reservoirs situated in watercourses need to have usable storage capacity of at least two years average demand with allowances given to:

- evaporation, seepage, siltation and ice formation losses;
- hydrological records and characteristics of the contributing drainage area;
- future demand increases; and
- current and future demands of other applicable users.

Direct in-stream supplies shall have sufficient flow to meet forecast peak demands at all times and consideration needs to be given to operational practices of current and foreseeable upstream water development projects.

Where a watercourse has highly variable flows and/or water quality, consideration needs to be given to the provision of off-stream storage to ensure use of adequate water supplies of the best available quality. The capacity of off-stream storage shall be based on the hydrological and quality characteristics of the primary supply.

### 2.2.2 Source Protection

During the selection of a surface water supply source, the impact of other users shall be reviewed with consideration given to:

- point and non-point sources of potential pollutants;
- potential for hazardous substance spills entering the supply;
- need for 1:500 flood protection of works;
- multipurpose use conflicts; and
- protection and activity controls near the intake.

### 2.2.3 Water Quality

Raw water quality shall be adequately defined or projected to account for seasonal and hydrological variations. In addition, the water quality evaluation needs to consider plankton and aquatic vegetation, sediments, wind and ice cover effects and groundwater inflows. The water quality assessment shall include variables that may affect water treatment or finished water quality parameters including those listed in Table 3 and Sections 26, 27, 28, 29, 30 and 31 and all sections of The Waterworks and Sewage Works Regulations and The Environmental Management and Protection Act, 2010, and the Saskatchewan Municipal Drinking Water Quality Objectives.

In general, supplies created by new impoundments or water development projects need to be assessed prior to the design of waterworks facilities. Where this is not feasible, projections based on upstream data or from similar impoundments within the drainage basin could be made.

### 2.2.4 Source Treatment

During the development of a supply project and particularly impoundments or reservoirs, efforts need to be undertaken to remove vegetation, organic soils or other materials which may adversely affect water quality. In addition, the hydraulic structure arrangement needs to accommodate flushing.

Consideration needs to be given to the potential needs and implementation of control programs for algae, aquatic weeds or other undesirable aquatic organisms. Consideration also needs to be given to the potential needs, benefits and methods for *in-situ* treatment like aeration.

### 2.2.5 Intakes

In addition to economic and construction factors, intake-siting considerations shall include:

- water quality;
- water circulation patterns;
- bank stability and localized erosion potential;
- bottom sediment buildups and silting potential;
- accessibility;
- protection from other users; and
- location of outfalls.

Intakes shall be accurately marked or mapped to enable their location during any season. In water supplies susceptible to vertical water quality variations, inlets are to be placed to allow withdrawal of the best water quality. In general, inlets should to be placed no lower than 0.75 m (2.5 ft.) off the bottom and the top inlet should be at least 2 m (6.5 ft.) below the low surface level where depths permit.

Intakes shall be designed to prevent entry of fish and debris and entrance velocities need to be kept to a minimum especially where frazil ice may be a problem. On large intakes, mechanical screening is recommended. For small gravity intakes, a means of back flushing needs to be provided.

Where use of submerged infiltration-type intakes are proposed for small capacity facilities, consideration needs to be given to the potential water quality impact of the media and the capability for periodic cleaning and/or replacement of the media face.

### 2.3 Groundwater

#### 2.3.1 Hydrogeological Characteristics

The long-term safe yield and recommended pumping rate of a well supply shall to be established. The following information shall be obtained:

- pump test and recovery data and curves;
- depth and extent of the aquifer;
- geological profile of the aquifer overburden;
- probable source of aquifer recharge;
- location and characteristics of observation wells; and
- GUDI (Groundwater Under Direct Influence of Surface Water) status.

#### 2.3.2 Source Protection

Wells shall be sited away from existing or potential sources of pollution and shall be located or suitably protected from flooding. GUDI status shall be determined for all new wells. Further information on GUDI is available in the publication Groundwater Under the Direct Influence of Surface Water Assessment Guideline. Land use and agricultural practices around a well and a recharge area, if defined, needs to be assessed and, if appropriate, measures instituted to ensure protection of the groundwater supply. The purpose of a Wellhead Protection program is to provide an organized approach to effectively protect groundwater drinking water supplies from contamination. Protection of groundwater sources for public water supplies will help to ensure safe sources of drinking water into the future and prevent costs due to contamination. Completing a Wellhead Protection Plan will identify concerns and lead a waterworks owner to understand how best to protect their own groundwater sources. Further information on well protection is available in the publication Wellhead Protection.

Where artificial recharge is proposed, the source water shall be free of contaminants. A sample of the proposed source water shall be analyzed. Drilled wells shall be of watertight construction to exclude contamination from the surface and shall be designed to seal off formations that are, or may be, contaminated or yield undesirable water. Provision shall be made for proper disinfection of the well during drilling, construction, and repair operations.

Observation wells when not being used must be properly sealed to prevent the entry of surface water, dirt or other material into the well.

#### 2.3.3 Water Quality

Water quality information including specific conductance, pH, alkalinity, hardness, iron, manganese, sulphates and nitrates shall be obtained prior to well development for a *preliminary* water quality assessment. Reliable field test equipment may be used for performing the preliminary water quality assessments. In addition, these variables shall be determined during pump testing.

#### 2.3.4 Other Design Considerations

Wells shall have year-round accessibility for inspections, measurements, cleaning, and repair purposes. Provisions can be made for regular water level measurements in production and observation wells and periodic acidizing and disinfection of production wells as may be required.

### 2.4 Pumping Stations

#### 2.4.1 Siting and Construction

Pumping stations shall be readily accessible at all times for inspections, maintenance and repair functions. The station shall not be subject to negative impacts from flooding during 1:500 events.

Consideration shall be given to:

- provision of adequate space for servicing, potential pre-treatment additions and the installation of additional units;
- protection of the station against vandalism and unauthorized entries;
- facilities and openings for the servicing, removal and replacement of equipment;
- appropriate frost protection, heating, ventilation and lighting.
- drainage and discharge of wastewaters; and
- safe siting and storage of fuels and chemicals or other potential contaminants.

For wells, the casing shall extend at least 0.2 m (8 inches) above the pump house floor and all piping or conduit entrances into the well shall be adequately sealed to prevent the entry of contaminants. Where pitless well units are considered desirable for particular applications, the following features shall be incorporated:

- watertight construction and tightly connected to the casing;
- extension of at least 0.4 m (16 inches) above final ground elevation and not subject to flooding;
- access for well disinfection and water level measurements; and
- protection against the entry of contamination through the top cap, electrical conduits or casing vent.

#### 2.4.2 Pumping

Pumping capacity shall be consistent with the supply and aquifer capacity and the water treatment capability. In general, for single supply sources, the pumping rate should be equal to or greater than the maximum daily demand based on the plant's operating time.

The number of pumps required shall be consistent with the pattern of flow requirements and the method of flow control. At least two pumps are recommended for single surface supply sources. Pumping capacity shall be met with the largest pump out of service. Pumps need to be chosen to operate over a full range of flows and shall have adequate control valving installed.

Where only one pump is used to service small waterworks, consideration shall be given for emergency or standby units.

#### 2.4.3 Controls and Appurtenances

Where pumping stations are relatively remote, consideration shall be given to providing automatic standby equipment in the event of power failure. Remote controlled stations shall have signals to indicate the station is out of service and that water is being delivered. Manual overrides shall also be provided. Pumps shall have individual discharge pressure gauges. Consideration shall be given to measurement of pump discharge rates. Discharge lines shall have water sampling facilities.

### 2.5 Supply Pipelines

#### 2.5.1 Capacity

Pipeline capacity shall be based on maximum day demands with consideration given to supply and treatment capacities and potential demands within the life of the pipeline.

#### 2.5.2 Materials

Supply lines shall be of durable material and pipe, fittings and appurtenances shall conform to applicable standards or specifications issued by AWWA, CSA, CGSB or other acceptable references. Pipe selection shall be based on careful consideration of pressure regimes including transient pressures such as surge and external loading. In addition, the material shall be assessed with respect to both external and internal corrosion potential. Where necessary, corrosion protection measures shall be incorporated.

Interior lining shall conform to AWWA standards if available. Consideration shall be given to potential water quality effects from the lining.

#### 2.5.3 Location

Where possible, supply pipelines shall be located in stable areas and where the line is readily accessible for repair. Care needs to be taken to avoid installation near areas of potential contamination. Sufficient bury shall be provided to prevent freezing with special attention given to road crossings. Consideration shall be given to grading the line to facilitate draining and the installation of drainage facilities.

#### 2.5.4 Appurtenances

Air release valves shall be provided at high points along the line where needed. The use of reliable automatic valves should be considered on long lines. Air release valves shall be protected from damage and accessible for testing or repair.

Isolation valves shall be considered for long pipelines and placed at the terminal ends of underwater crossings to facilitate testing or repairs. Valve locations shall be well marked and readily accessible. Valve selection shall include considerations for minimizing water hammer and the use of pipeline cleaning materials such as pigs or swabs.

Pipeline design shall consider flushing, cleaning, and disinfection requirements during construction and subsequent use. For pipelines susceptible to chemical or biological deposits, provisions for pig or swab launching and exit facilities should be made.

Where supply connections are made for other users in addition to the engineering and operational problems, consideration should be given to the execution of agreements covering water quality aspects and for the prevention of cross-connection.

Backflow prevention devices shall be installed to prevent backflow occurring at the point of a cross-connection. It is important that the backflow prevention device match the particular hydraulic conditions at that location and be suitable to protect against the degree of hazard present.

## 3. Treatment

### 3.1 General

### 3.1.1 Objectives

The objectives of a public water supply system are to provide safe and aesthetically appealing water to the customers without interruption and at a reasonable cost, an adequate quantity of water at sufficient pressure for fire protection and industrial water for manufacturing. Treated water quality shall meet requirements including those listed in Table 3 and Sections 26, 27, 28, 29, 30 and 31 and all sections of The Waterworks and Sewage Works Regulations and The Environmental Management and Protection Act, 2010, and should meet Saskatchewan Municipal Drinking Water Quality Objectives.

### 3.1.2 Selection of Water Treatment Processes

Selection of a suitable water treatment process for a given utility is typically a complex and diverse task. Conditions are likely to be different for each water utility, adoption of an appropriate water treatment process by a water utility is influenced by the necessity to meet the regulatory requirements and guidelines, the desire of the utility and its customers to meet other water quality standards and objectives and the need to provide water service at the lowest reasonable cost. A water treatment plant shall be designed considering the fact that it shall supply continuous and safe water to the customers regardless of the raw water characteristics and the environmental conditions. Hence, the selection of treatment process is important in the plant design. The ultimate plant design has a system that is proven to be simple, effective, reliable, durable and cost-effective.

The design of water treatment plant starts with the preliminary studies that include:

- design period;
- water supply areas – identifying the areas to be served;
- population – estimating the present and future population;
- estimating maximum daily water demand;
- evaluation and selection of the water source;
- size of the treatment plant;
- location of the treatment plant site; and
- financing.

Engineers/designers should conduct a preliminary engineering study and consider the following basic rules prior to design work:

- standards and objectives of the finished water quality;
- source treatment and potential water quality changes during supply transmission;
- treatability of raw water – various treatment options to be considered;
- recommend a treatment process that is cost-effective;
- keep an alternate treatment process;
- design a plant that is easy to construct and safe to operate; and
- confirm that the plant meets the structural and geotechnical design specifications, hydraulic grade across the plant and legal requirements.

Where a treatment facility serves more than one supply source, careful consideration shall be given to ensuring the treatment processes are applicable and compatible for each of the sources.

The selection of package treatment plants and special proprietary devices or processes should be based on proper consideration of:

- raw water condition and demand variability;
- operation and maintenance;
- servicing, repairs or replacement; and
- operational flexibility.

### 3.1.3 Capacities

The water treatment plant production capacity shall be on the basis of the maximum day demand at the design year with consideration also given for capacity to address storage or fire flow needs.

Treatment process capacity shall be based on the plant production capacity, the in-plant water use and allowances for treatment component downtime such as filter washing. Consideration also shall be given to capacity restrictions during periods of worst water quality. Where feasible, recycling of non-sanitary wastewater should be considered.

Treatment capacities shall consider future expansion needs and allowances should be made for logical staging of process units.

### 3.1.4 Plant Siting

The site evaluation is based primarily on the distance from the site, the layout of treatment units and the method of water distribution (gravity or pumping). Further, the following items must be considered in evaluation of the treatment plant site:

- neighbouring land use compatibility;
- availability of electric power and utilities;
- accessibility for vehicles including supplies and equipment transport;
- susceptibility to flooding;
- foundation stability;
- provision for future plant expansion; and
- plant wastewater disposal facilities.

### 3.1.5 Building Construction

Construction shall be in accordance with applicable building standards and bylaws and should, as much as possible, be aesthetically compatible with neighbouring developments. Plants shall be of fire resistive construction and protected against vandalism and unauthorized entry. The building should have access allowances for removal, replacement or addition of process equipment. Energy conservation measures, where practical, should be incorporated into a building design.

Interior finishes should be durable and easily cleaned. Floors shall be finished to provide a smooth, dust free surface and graded to provide adequate drainage. Consideration shall be given to ensure products or materials of construction will not affect water quality for both raw and treated water.

### 3.1.6 Building Services

For the design and installation of building services, reference shall be made to applicable codes, legislation and approval requirements. Buildings should have adequate lighting throughout with special consideration given to areas requiring close inspections and equipment adjustment or maintenance.

Fuel storage shall be sited and protective measures incorporated to avoid any potential contamination of raw or treated water.

Water service shall be provided from a source that has had full treatment including adequate disinfection contact time. Consideration should be given to the provision of a hot water supply for sanitary and cleaning purposes. The water system shall be properly protected from any cross-connections.

Electrical systems shall be adequate to accommodate peak usage plus reserves for maintenance and repair equipment and potential upgrading. Main switch gear should be located above grade and shall not be subject to flooding. Adequate electrical outlets should be provided for maintenance and other services.

Adequate heating should be provided with control levels depending on the type of area being heated. Consideration should be given to the provision of adequate building ventilation especially for below grade facilities and for dehumidifying needs.

### 3.1.7 Safety and Cross-Connection Control

The plant shall comply with current occupational health and safety regulations. All necessary safety and protective equipment shall be available at the time of plant start-up. Attention is typically given to recommended safety measures as provided by suppliers of equipment and chemicals.

The floor of every water treatment facility shall be designed so that drainage occurs only into the floor drains or sumps. All pipes that connect the discharge pipe from a treatment component in a water treatment facility to a sanitary sewer shall be equipped with a backflow prevention device that is, in the opinion of the Water Security Agency, effective, as seen in Section 5.1. Every water treatment facility shall be equipped with a meter that records the volume of water passing through the water treatment facility. It is recommended that raw water, treated water and plant wastewater be metered, the minimum requirement is metering of either raw or treated water volumes. Every chemical feeder in a water treatment facility is to be equipped with a device that is capable of adjusting the rate of chemical applied. Every water treatment facility is to be maintained in a clean and orderly condition satisfactory to the minister.

### 3.1.8 Piping and Appurtenances

All piping and appurtenances shall be manufactured in accordance with AWWA, CSA, ASTM or other recognized standards. Material selection should include consideration of corrosion, maintenance and required connection factors. Piping shall have appropriate supports and restraints. For connections through a structure, a flexible coupling should be provided if the possibility of settlement exists.

Piping shall be arranged so that all valves, meters or other appurtenances are conveniently accessible. Proper consideration should be given to installation of drains, air release valves and cleanouts and flushing facilities where applicable. A totalizing water meter shall be provided and additional flow measuring devices should be installed as applicable to the treatment units. Piping shall be designed with flow velocities based on process, hydraulic and retention time considerations.

It is recommended that piping be adequately identified as to contents and direction of flow. Where a facility does not have a standardized colouring or marking code, one shall be adopted. The recommended colour code for the Water Treatment Plant Piping as per the “Ten State Standards” is shown in Table 3.1.

**Table 3.1 Water Treatment Plant Piping – Recommended Colour Code**

| Pipes | Colour |
|---|---|
| ***Water Lines***: | |
| Raw Water | Dark Green |
| Potable or Finished Water | Blue |
| Settled or Clarified water | Aqua |
| ***Chemical Lines:*** | |
| Alum or primary coagulant | Orange |
| Ammonia | White |
| Carbon Slurry | Black |
| Caustic | Yellow with Green Bands |
| Chlorine (Gas or solution) | Yellow |
| Fluoride | Light Blue with Red Bands |
| Lime Slurry | Light Green |
| Ozone | Yellow with Orange Bands |
| Phosphate Compounds | Light Green with Red Bands |
| Polymers or Coagulant aids | Orange with Green Bands |
| Potassium Permanganate | Violet |
| Soda Ash | Light Green with Orange Bands |
| Sulfuric Acid | Yellow with Red Bands |
| Sulfur Dioxide | Light Green with Yellow Bands |

| | |
|---|---|
| ***Waste Lines***: | |
| Backwash Waste | Light Brown |
| Sludge | Dark Brown |
| Sewer (Sanitary or other) | Dark Gray |

Notes:
1. The direction of flow and name of contents be noted on all lines.
2. The entire length of pipe to painted with recommended colour.
3. Bands, if necessary are to be located as follows:
   (a) at 9 m intervals, and/or
   (b) where the pipe enters and leaves a room.
4. Individual bands are to be 25 mm wide and a 25 mm space is to be left between bands.

### 3.1.9 Operations and Maintenance

Suitable storage arrangements should be provided for parts, tools and other materials consistent with the treatment facility and maintenance needs. Consideration should be given for suitable working areas and bench facilities. Where possible, an office area should be provided to include a desk or working table and storage for manuals, records, plans and relevant documents/books.

Suitable operations and maintenance manuals shall be prepared and readily available to operating personnel at all times. It is suggested that the manuals include:

- drawings, installation descriptions, recommended lubrication and maintenance schedules, special operation and/or maintenance features, calibration requirements, spare parts listing, warrantees and parts and repair availability for all equipment;
- basic operating procedures.
- recommended testing and record keeping program;
- description of finishes; and
- any emergency procedures and troubleshooting instructions that may be applicable.

### 3.1.10 Personnel Facilities

Depending on the time period the plant is manned and the number of operating personnel, consideration should be given to provision of sanitary facilities, apparel storage and lunch and meeting room.

### 3.1.11 Monitoring, Surveillance

Sufficient and suitable sample taps shall be provided to enable collection of representative water samples to assess the performance of the treatment units.
Analytical equipment and laboratory facilities should be provided with consideration given to:

- source water quality and its variability;
- treatment processes - their complexity, adjustment opportunity and performance assessment;
- operating personnel capability;
- optional analytical availability; and
- acquisition of reagents and equipment parts.

As a minimum, analytical equipment shall be provided for conducting:

- free and total chlorine residual determination;
- turbidity determination;
- fluoride residual determinations where water is fluoridated;
- jar testing where coagulation-flocculation is practiced;
- iron determination where iron removal is required; and
- manganese determination where manganese removal is provided.

Appropriate forms shall be devised for maintenance of water treatment infrastructure, records for water usage, process operations and analytical test data.

### 3.1.12 Wastewater

All sanitary wastes shall be segregated within the plant from process wastewaters and discharged to a sanitary sewage works or provided acceptable on-site or off-site treatment. Consideration should be given to recycling of process wastewaters where feasible.

### 3.1.13 Filter Backwash and other Process Waters

Backwash water and thickener supernatant may contain high concentrations of pathogens including *Cryptosporidium* oocysts. Recycling of these waters might reintroduce contaminants that were removed during treatment. If adequate treatment of these waters is not provided before being returned, significant numbers of pathogens might re-enter the plant. Water treatment plants shall discharge backwash and other process waters into sanitary sewers, separate storage ponds or sedimentation tanks. The hydraulic capacities of the sewage works shall be assessed and discharge controls provided if necessary. The discharge of such streams to other than sanitary sewage works shall be carefully assessed to determine treatment requirements and discharge arrangements.

Recycling of these waters may be possible after gravity settling in storage ponds to ensure settling of solids at the bottom. The supernatant from the storage ponds may be returned prior to the point of primary coagulant addition.

Clarifier sludges shall receive a minimum of sedimentation. The disposal of concentrated sludge should be considered.

The publication Managing Wastes Generated by Water Treatment, Distribution, Maintenance, Repair and Extension contains additional information to be followed for treatment and disposal of water treatment plant wastes.

## 3.2 Surface Water and Groundwater under Surface Influence

### 3.2.1 Processes

A water treatment plant shall be designed to ensure that t the treated water meets turbidity and other water quality standards specified in legislation. In general, treatment facilities for a surface water source or groundwater source directly affected by surface water (GUDI) should include screening, coagulation-flocculation, sedimentation, filtration, taste and odour control and disinfection. A water treatment plant designed for the treatment of surface or GUDI water should provide greater than 3-log (99.9%) removal and/or inactivation of *Giardia lamblia* cysts and *Cryptosporidium parvum* oocysts and 4-log (99.99%) removal and/or inactivation of viruses. In order to provide a multi-barrier approach to water treatment, a minimum of at least 0.5-log removal and/or inactivation of *Giardia lamblia* cysts and 2-log removal and/or inactivation of viruses shall be provided through disinfection. At such time as future requirements related to source water quality and elevated levels of *Giardia lamblia cysts*, *Cryptosporidium parvum oocysts* and viruses in source water are implemented, additional removal/inactivation of these organisms may be required and should be considered in advance during design of the works. If treated water turbidity meets the prescribed limits set out in section 30 of The Waterworks and Sewage Works Regulations, the removal/inactivation credit for *Giardia, Cryptosporidium* and viruses as a function of treatment processes are shown in Table 3.2.

**Table 3.2 Log Removal/Inactivation for Treatment Processes***

| Process | ***Giardia* cysts** | ***Cryptosporidium parvum* oocysts** | **Virus** |
|---|---|---|---|
| Conventional sedimentation/filtration credit | 3 | 3 | 2.0 |
| Direct filtration credit | 2.5 | 2.5 | 1.0 |
| Slow sand filtration credit | 3 | 3 | 2.0 |
| Diatomaceous earth filtration credit | 3 | 3 | 1.0 |
| Microfiltration | Demonstration using challenge testing | Demonstration using challenge testing | No credit |
| Ultrafiltration | Demonstration using challenge testing | Demonstration using challenge testing | Demonstration using challenge testing |
| Nanofiltration and Reverse Osmosis | Demonstration using challenge testing | Demonstration using challenge testing | Demonstration using challenge testing |

*A minimum of at least 0.5-log removal and/or inactivation of *Giardia lamblia* cysts and 2-log removal and/or inactivation of viruses must be provided by disinfection, regardless of the treatment process used.

In the selection of a water treatment process, consideration shall be given to provide appropriate control measures to control the disinfection by-products (DPBs) that are formed during the disinfection process. However, this must not be done in a manner that would compromise the efficiency of the disinfection process. Special treatment processes for controlling the specific contaminants will have to be reviewed on an individual basis. Log removal of any required cryptosporidium, giardia or virus by membrane or UV must be proven by challenge test data or similar data, typically this is available from the manufacturer. UV and membrane performance claims may be de-rated by the Water Security Agency.

### 3.2.2 Chemical Application

Care shall be taken to select chemicals that do not contain excessive impurities. All chemicals must be approved for water use as seen in Section 27 and other sections of The Waterworks and Sewage Works Regulations and other relevant Water Security Agency information. Approval agencies include Health Canada, National Sanitation Foundation and US Environmental Protection Agency. Requirements of other agencies in terms of labeling, storage, safety, spill control and other factors shall be considered. According to Section 27 of The Waterworks and Sewage Works Regulations, all chemicals added to drinking water during its treatment, storage and distribution must be certified in accordance with the criteria specified in *NSF International (NSF)/American National Standards Institute (ANSI) Standard 60: Drinking Water Treatment Chemicals – Health Effects*. The dosage of each chemical shall: (a) not exceed the dosage specified as Maximum Use of each chemical product in Standard 60, unless otherwise authorized in writing by the Approval Engineer; and (b) be calculated in milligrams of chemical per litre of water (mg/L) by measuring the amount of chemical added in a period not exceeding seven calendar days divided by the total volume of water to which the chemical was added in that time period. More information is available in publication Use of Chemicals in Drinking Water Treatment.

Use of coagulant or flocculant aids shall be based on appropriate bench or pilot testing for the specific water supply. Polyelectrolytes or other aids shall be suitable and approved for use with water. Special consideration should be given to mixing needs, chemical agency application points, and dosage control.

Chemicals shall be stored and handled in an appropriate manner. Containers shall be fully labeled to include chemical name, purity and concentration and supplier name and address. Segregated, interior storage space should be provided if possible with consideration given to:

- maintenance of inventory for at least 30 days supply unless short notice deliveries are assured;
- unloading and handling conveniences;
- maintenance of dry conditions;
- compatibility of chemicals or species hazards;
- protection from adulteration and spills; and
- suitable ventilation.

Drains from chemical storage and containment areas are not allowed unimpeded drainage into sewers. Chemicals and any material with a deleterious impact to the environment must be neutralized before disposing to the sewer system.

For critical operations like disinfection and coagulation, standby feeders shall be available. Chemical feed equipment shall have appropriate dust and gas control measures and siting considerations should include proximity to application points and accessibility for servicing, repair and observations. Measures shall be taken to avoid potential cross-connection problems with water and potential chemical syphoning. In addition to ensuring feeders are suitable for the form and characteristics of the chemical, selection considerations shall include:

- adequate capacities to meet anticipated maximum dosages;
- ability to control feed rates; and
- reliability of operation, availability of parts and repairs and repair capability.

Chemical application points should be carefully evaluated for such factors as:

- treatment efficiency;
- safety to operators;
- flexibility for process modifications;
- mixing;
- antagonistic effects of different chemicals;
- impact on facility materials; and

- feed line maintenance.

### 3.2.3 Aeration

Aeration is effective for removing dissolved gases and highly odorous compounds such as hydrogen sulfide. Aeration is often the first step in treating impounded surface waters or well water, and may be used to achieve any of the following: removal of hydrogen sulfide; reduction of dissolved carbon dioxide; and addition of dissolved oxygen for oxidation of iron and manganese. Examples of aeration processes include diffused mechanical nozzle spraying, multiple tray cascading and packed tower type.

Forced or induced draft aeration devices shall be designed to ensure even water distribution, adequate counter currents of air and proper external exhausting. As a guide, the loading should be within the range of 0.7 to 3.4 L/s per $m^2$ of total tray area (0.8 to 4 gpm/$ft^2$) and 5 or more trays used with separations not less than 150 mm (6 inches). Where pressure aeration is proposed for oxidation purposes, consideration should be given to compressed air quality and mixing, the scaling potential of the water and subsequent air release. Aerators should have a bypass and provisions made for inspection and cleaning of the devices. Exhaust gases shall be vented outside the building.

### 3.2.4 Coagulation – Flocculation

Coagulation is used to destabilize the charge on colloids and suspended solids, including bacteria and viruses. Flash mixing is an integral part of coagulation. To achieve proper coagulation, high intensity rapid mixing is considered necessary. It is recommended that rapid mixing be accomplished by either an in-line mixing device or mixing in a separate process tank. Typical energy gradients (G values) would be in the range of 1000 $sec^{-1}$. It is recommended that some flexibility be provided in rapid mix design if possible.

Flocculation is the gentle mixing phase that follows the dispersion of coagulant by the flash mixing unit that is necessary to condition the suspended material for subsequent treatment. The design of flocculation systems should allow for low velocities and avoidance of rapid acceleration to ensure maintenance of a good floc. When designing a flocculation process, selection of the mode of mixing and determination of the physical relations and characteristics of the flocculation tanks and clarifiers (sedimentation tanks) should be among the first decisions to be made; either hydraulic mixing or mechanical mixing may be chosen. Where sedimentation follows flocculation, the retention time for floc formation should be at least 30 minutes.

Flocculation tanks should be designed to permit flexibility of operation and for ease of maintenance and cleaning. Features that should be considered are a minimum of two tanks and appropriate drainage and access for removal of sludge and basin cleaning.

Consideration of mechanically or hydraulically mixed tanks should ensure sufficient flexibility of operation is possible and that G values can be varied to approach optimum flocculation. Incorporating the flocculation basin into the clarifier unit is considered as the most efficient and economical design.

The general basic criteria for a basic rectangular flocculation tank with 2 to 6 flocculation stages are as follows:

| | |
|---|---|
| Energy input | $Gt = 3\times10^4$ to $2\times10^5$<br>t is in seconds ($5\times10^4$ average)<br>or<br>$G = 10$ to $70\ S^{-1}$ ($30\ S^{-1}$ average) |
| Detention time | 20 to 30 min at maximum daily flow rate. |

### 3.2.5 Sedimentation Tanks (Clarifiers)

This process is designed to remove a majority of the settleable solids by gravitational settling, thereby maximizing the downstream unit processes such as filtration. The factors that influence sedimentation efficiency include:

- surface overflow rate (also known as surface loading rate);
- inlet and outlet arrangements;
- type of sedimentation tank;
- raw water characteristics; and
- local climate conditions.

There are three main configurations for sedimentation tanks: horizontal rectangular basins; upflow sedimentation tanks; and upflow clarifiers with sludge blanket. Regarding application, rectangular sedimentation tanks are suited to large-scale plants, whereas upflow and sludge blanket clarifiers are suited to small and mid-sized water utilities where the rate of flow and raw water quality are constant. The design details for some basic types of sedimentation tanks are shown in Table 3.2. Sedimentation tanks shall be designed on the basis of surface overflow rates (surface loading rates) with due consideration given to the type of floc generated and water temperature. Inlets of the sedimentation tanks should provide equal distribution and uniform velocities that maximize the opportunity for particles to settle. Outlets shall be designed to maintain settling velocities and to minimize short-circuiting.

The sedimentation tank should be designed to accommodate the preferred method of sludge removal. Where a tank must be removed from service for cleaning, it is recommended that at least two tanks be provided. Consideration should be given to ice formation potential, bypasses, overflows to prevent plant flooding and means for observing the settling performance.

Where tube settlers are used, the following should be considered:

- tank overflow rate of 3.8 to 6.3 m/h (1.3 to 2.1 gpm/ft$^2$) for cold regions;
- maximum underflow velocity of 1 m/min (3.3 ft/min); and
- maximum velocity across the top of the tubes of 0.15 to 0.2 m/min (0.5 to 0.65 ft/min).

**Table 3.3 Design Details for Sedimentation Tanks**

| Type of Sedimentation Tank | Some Design Details |
|---|---|
| Rectangular Tanks | Surface overflow rate: 0.8 – 2.5 m/h (0.27 – 0.83 gpm/ft$^2$)<br>Detention time: 1.5 – 3 h<br>Water depth: 3 – 5 m<br>Width/Length: > 1/5<br>Weir loading: < 11 m$^3$/h.m (12.3 gpm/ft) |
| Upflow Clarifiers | Surface overflow rate: 1.3 – 1.9 m/h (0.43 – 0.63 gpm/ft$^2$)<br>Detention (settling) time: 1 – 3 h<br>Water depth: 3 – 5 m<br>Weir loading: 7 m$^3$/h.m (7.8 gpm/ft)<br>Upflow velocity: < 3 m/h |
| Sludge Blanket Clarifiers | Surface overflow rate: 2 – 3 m/h (0.67 – 1 gpm/ft$^2$)<br>Detention (settling) time: 1 – 2 h<br>Weir loading: 7 - 15 m$^3$/h.m (7.8 – 16.77 gpm/ft)<br>Upflow velocity: < 0.6 m/h<br>Flocculation time: approximately 20 min |

Note: Surface overflow rate: m/h = (m$^3$/m$^2$.d) ÷ 24; 72 m$^3$/m$^2$.d = 1 gpm/ft$^2$.
Weir loading: m$^3$/m.h = (m$^3$/m.d) ÷ 24; 175 m$^3$/m.d = 8.15 gpm/ft.

### 3.2.6 Filtration

In general, a minimum of two filters should be provided, with a design working capacity equal to the plant capacity and each capable of independent operation and backwash. In larger facilities with more than two filters, production capacity shall be equal to or greater than the maximum plant capacity with the largest filter removed from service.

#### 3.2.6.1 Gravity Filtration

Gravity filters are comprised of porous granular material, and these filters commonly use a substantial depth of sand or anthracite coal or granular activated carbon or combinations thereof. Gravity filtration, also known as 'rapid sand filtration' or 'rapid granular filtration' typically has a filtration rate in the range of 5 and 12.5 m/h (1.67 to 4.17 gpm/ft$^2$). Filtration rate is a function of factors such as the size of the filter media, the quality of raw water, the degree of pretreatment and the quality control measures. In certain instances, the filtration rate can exceed 12.5 m/h (4.17 gpm/ft$^2$) based on the demand of produced water or raw water characteristics or type of filter media used or combinations thereof. The details about the filter media used in the filtration process are shown in Table 3.3. Filter media shall be durable and conform to applicable specifications such as AWWA specifications.

The design of a gravity filter should provide:

- adequate headroom above the filter to permit inspection and operation and provide reasonable access to the filters for observation;
- protection against floor drainage entering the filter, by means of a suitable curb or roof drainage entering the filter;
- an overflow to prevent flooding, unless provided elsewhere in the raw water supply system;
- a means of cleaning influent pipes or conduits where solids loadings are high;
- effluent piping arranged to prevent backflow of air into the filter;
- a means of drainage and a waste wash-water drain of sufficient capacity;
- operation with a minimum water depth in excess of the design terminal head loss to prevent negative pressure and air binding of the filter;
- an acceptable method of regulating flow; and
- indicating instruments at least for loss of head and rate of flow.

Filter media depths should not be less than 600 mm (24 inches). As a guide, a gravity filter could consist of a lower layer of silica sand, not less than 200 mm (8 inches) deep and an upper layer of anthracite coal not less than 450 mm (18 inches) deep. The use of multi-media or proprietary mixed media designs should be based on examination of data and operating experience to demonstrate their suitability.

Appropriate support media shall be provided and shall be consistent with the underdrain and wash water distribution system characteristics.

Filter bottoms or underdrains shall be designed to provide uniform distribution of backwash water and/or scouring air. Porous plate bottoms should not be used with waters high in iron or manganese, scale forming waters or those susceptible to algal or other biological growths. Filter bottom design should be such that essentially all head losses in backwashing occur at the final openings. Careful consideration should be given to the type of filter operation to be employed such as declining rate filtration, influent flow splitting, and constant rate filtration.

The appropriate backwash rate should be determined based on the specific gravity of the media, the size of the media grains and the water temperature. The backwash rate, usually recommended in the filtration process, should fall in the range between 36 and 45 m/h (12 – 15 gpm/ft$^2$). There shall be enough headspace over the filter media for the expansion of the media during backwashing procedures.

Designers/Engineers should consider several additional issues when designing a granular bed filtration process: the use of wash troughs, the amount of allowable headloss for filtration, the type of underdrain, type of filter and waste wash-water handling facility.

**Table 3.4 Types of Filter Medium and Design Details**

| Filter Medium | Design details |
|---|---|
| Fine Sand | Effective size: 0.25 – 0.35 mm<br>Uniformity coefficient: 2 – 3<br>Depth: 1 – 1.2 m (3.3 – 4 ft) |
| Medium Sand | Effective size: 0.45 – 0.65 mm<br>Uniformity coefficient: 1.4 – 1.7<br>Depth: 0.6 – 0.75 m (2 – 2.5 ft) |
| Coarse Sand | Effective size: 0.8 – 2 mm<br>Uniformity coefficient: 1.4 – 1.7<br>Depth: 0.8 – 2 m (2.6 – 7 ft) |
| Multi Media – dual or trimedia (sand-coal-garnet) | <u>Sand</u><br>Effective size: 0.45 – 0.65 mm<br>Uniformity coefficient: 1.4 – 1.5<br>Depth: 0.3 m (1 ft)<br><u>Anthracite coal</u><br>Effective size: 0.9 – 1.4 mm<br>Uniformity coefficient: 1.4 – 1.5<br>Depth: 0.45 m (1.5 ft)<br><u>Garnet</u><br>Effective size: 0.25 – 0.3 mm<br>Uniformity coefficient: 1.2 – 1.5<br>Depth: 0.0075 m (0.25 ft) |

| | |
|---|---|
| Granular Activated Carbon (GAC) | Effective size: 0.5 – 1 mm<br>Uniformity coefficient: 1.5 – 2.5<br>Depth: 1.8 – 3.6 m (6 - 12 ft) |

Considerations shall include ensuring production of acceptable filtered water and also plant operational capabilities. Wash water troughs should be designed to ensure suitable discharge capacity and to enhance good filter washing. Filter backwash provisions shall ensure sufficient rates for suitable filter media expansion. Auxiliary water or air wash systems are recommended. Filter to waste provisions shall be provided.

#### 3.2.6.2 Pressure Filtration

Pressure filters are used at times for rapid filtration. The water to be filtered enters the filter under pressure and leaves at slightly reduced pressure because of the headloss encountered in the filter media, underdrain and piping connections. In general, one of the best applications of pressure filters is the filtration of pumped, deep-well water containing iron and manganese. Use of pressure filters for surface water treatment should be limited to plants with a design capacity less than 3.5 L/S (46 gpm) and where good coagulation/flocculation and sedimentation facilities are available.
In general, filtration rates should not exceed 12.5 m/h (4.17 gpm/ft$^2$). For pressure filters, consideration should be given to:

- sufficient side wall shell height to accommodate desired media depths and bed expansion;
- filter shell corrosion protection;
- air release valves;
- an accessible manhole for inspection and repairs on all filters greater than 1 m diameter;
- measures to enable backwash water observations;
- provision for controlling flow rates for each filter; and
- provision of adequate sampling taps to monitor quality at appropriate points in the filter.

#### 3.2.6.3 Direct Filtration

Direct filtration is a surface water treatment process that includes coagulation, flocculation and filtration. In certain cases, the flocculation unit is omitted and the process is referred to as *in-line filtration*, with flocculation occurring in the filter itself. Direct filtration shall only be used where appropriate water quality treatment studies demonstrate successful application of the process and adequate monitoring and operational surveillance are available.

#### 3.2.6.4 Slow Sand Filtration

Slow sand filters are operated at very low filtration rates and the grain size of the sand is smaller than that used in a rapid sand filter. A unique feature of slow sand filters is the presence of a thin layer of media on the surface of the filter bed known as ‘Schmutzdecke’. This layer, composed of dirt and living and dead micro and macro-organisms from the water, becomes the dominant filter media as the filter cycle progresses.

The general design criteria for the slow sand filter system are listed below:

- Filter bed area – 0.05 to 0.15 m$^2$ per capita per day.
- Number of filters – $n = 0.25\ Q^{0.5}$, where n is the number of filters and is greater than or equal to 2, and Q is the plant flow rate (m$^3$/h).
- Filtration rate – 0.04 to 0.42 m/h (0.01 to 0.14 gpm/ft$^2$).

In general, slow sand filters should be limited to cases where the raw water quality is suitable for this type of filtration and documentation is available to demonstrate the potential effectiveness to produce acceptable water quality. Filters designed to slow sand filter rates that are capable of being backwashed and then rapidly placed into service are not true slow sand filters.

#### 3.2.6.5 Other Filters

Filters, such as vacuum diatomaceous earth or cartridge filters, should only be used with high quality supplies and where the effectiveness can be demonstrated. Design of cartridge filter plants shall conform to the publication Cartridge Filter Permitting Guidelines.

### 3.2.7 Taste and Odour Control

Taste and odour control capabilities should be available for all surface water treatment facilities.

Control provisions should include consideration of:
- source water quality variability and treatment;
- treatment flexibility; and
- operational and maintenance capabilities.

### 3.2.8 Activated Carbon Adsorption

The selection of activated carbon for adsorption should be based on the purposes and flexibility and operational requirements.

Addition of powdered activated carbon (PAC) at selective points in the treatment system may be advantageous for taste and odor control. The primary characteristic of PAC that differentiates it from granular activated carbon (GAC) is particle size. The main advantages of using PAC are the low capital investment costs and the ability to change the PAC dose as the water quality changes. The disadvantages include high operating costs, low total organic carbon (TOC) removal and sludge disposal problems.

Use of PAC in the treatment system should include consideration of:
- contact time requirements;
- dosage and application point variability;
- wetting provisions; and
- dust control and chemical handling safety measures.

Granular Activated Carbon (GAC) is used as a substitute for filter media or as an additional process in the conventional treatment process, for the removal of organic compounds including DPBs, those producing taste and odor and pesticides.

GAC can be classified by the following characteristics:
- flow direction – upflow or downflow;
- configuration – parallel or series; and
- driving force – gravity or pressure.

Water may be applied to GAC either upflow or downflow. Downflow columns are the most commonly used in drinking water treatment. GAC gravity contactors usually find their application in medium and large-scale water treatment systems. GAC contactors shall be designed on the basis of contact time.
Additional factors that must be considered in the design of full-scale systems include:
- pretreatment;
- GAC particle size;
- hydraulic loading rate;
- Empty Bed Contact Time;
- backwashing;
- adsorption efficiency;
- biological activity and control of microbial growth; and
- replacement of the medium or regeneration frequency and method of regeneration.

### 3.2.9 Membrane Processes

Membrane processes mainly used in drinking water treatment are reverse osmosis (RO), nanofiltration (NF), electrodialysis (ED), ultrafiltration (UF) and microfiltration (MF). Membrane processes are used to separate impurities from water. The amount of purification depends on the type of membrane, the level of driving force and raw water characteristics.

Electrodialysis (ED) and electrodialysis reversal (EDR) processes are limited to treatment of ionic contaminants and are ineffective for pathogen and organic removal in most cases.

Membranes are often classified by their pore size. A reverse osmosis membrane rejects solutes as small as 0.0001 $\mu$m and nanofiltration membrane rejects solutes as small as 0.001 $\mu$m. Microfiltration and ultrafiltration membranes have a minimum solute rejection of 0.10 and 0.01 $\mu$m, respectively. The details about the membranes are summarized in Table 3.4. Cost is a major factor in the case of selection of a membrane process. Type of membrane, pressure, manufacturer's specification and guarantee are additional factors to be considered in the selection.

**Table 3.5 Details of the Membranes Applicable to Drinking Water Treatment**

| Process | Pore size | Pressure | Removal Objects |
|---|---|---|---|
| Microfiltration (MF) | 0.1 – 0.2 μm | 0.7 – 1.4 kg/cm$^2$ (10 - 20 psig) | Particulate and microbial |
| Ultrafiltration (UF) | 0.003 – 0.01 μm | 0.7 – 7.8 kg/cm$^2$ (10 - 40 psig) | Molecular size compounds, Particulate and microbial |
| Nanofiltration (NF) | 0.001 – 0.005 μm | 5.3 – 10.6 kg/cm$^2$ (up to 150 psig) | Natural organic matter (NOM), including color, Ca and Mg. |
| Reverse osmosis (RO) | < 1 nm | > 14 kg/cm$^2$ (> 200 psig) | Ionized salt ions and colloidal matter. |

Special consideration shall be given to the disposal of the membrane concentrate. Discharging of concentrate to local wastewater collection system is encouraged. Where the local wastewater collection system cannot handle the increased loading from the membrane concentrate, evaporation ponds should be considered as an alternative disposal method. Discharging of membrane concentrate to a receiving body of water should only be evaluated as a last resort and must only be done after careful consideration is given to the impacts of the concentrate on the receiving water. Selection of a particular disposal method depends on the local environmental conditions, costs and ease of conveyance and disposal. Concentrate disposal is a very important component of environmental protection and must be addressed early in the design and evaluation of any membrane process.

As membrane processes generate a significant amount of wastewater, consideration of wastewater disposal shall be considered early in the process. If the wastewater will be discharged to the local wastewater collection and treatment system, then these systems shall be evaluated to ensure that adequate capacity is available for the new loads.

### 3.2.10 Fluoridation

Fluoride feeding equipment shall be capable of maintaining feed rates within 5% of set rate. Where fluoridation is practiced, it is recommended the finished water contain 0.7 mg/L fluoride and shall never contain more than 1.5 mg/L fluoride.

### 3.2.11 Disinfection

Disinfection is the final component in the water treatment train and is designed to further reduce and/or inactivate the number of pathogenic organisms in drinking water. Disinfectants are also used for other purposes such as, taste and odour control, oxidation of iron and manganese and as a coagulation and filtration aid. The potential formation of disinfection byproducts (DBPs), such as trihalomethanes (THMs), haloacetic acids (HAA), chlorate, chlorite, bromate, aldehydes and ketones shall be considered when designing the disinfection system. The formation of DBPs depends on the type of disinfectant, the presence of organic material (e.g., TOC) and other environmental factors. The formation of DBPs can be minimized by removing the DBP precursors.

The factors to be considered in selecting a disinfection process are:

- raw water quality;
- the presence of surrogate organisms in the drinking water supply;
- the choice of using alternative disinfectants;
- the relationship between the concentration of the disinfectant residual (mg/L) and contact time (T);
- the formation of DBPs and their magnitude;
- safety problems associated with the disinfectants; and
- cost of disinfection systems.

The factors that affect the disinfection efficiency are:

- oxidizable substances in the process water;
- particulate concentration;
- temperature and pH;
- contact time; and level of desired disinfectant residual, if applicable.

Chlorine is the most commonly used disinfectant in drinking water treatment. Chlorination equipment shall be of adequate capacity to maintain a free chlorine residual throughout the system. Where feasible, and

especially for small facilities, consideration should be given to the use of sodium hypochlorite for ease in operation. Use of gas chlorine shall conform with the requirements set out in the publication Guidelines for Chlorine Gas Use in Water and Wastewater Treatment.
Other major disinfectants include chlorine dioxide, chloramines and ozone. The chemical chlorine dioxide has been used extensively as a drinking water disinfectant around the world. Chlorine dioxide is also used for industrial process water and air treatment, food production and waste disinfection. Chlorine dioxide is one of a number of disinfectants that are effective against *Giardia Lamblia* and *Cryptosporidium* parasites. Chlorine dioxide can be used as an oxidizing agent and as a disinfectant. Chlorine dioxide is a known disinfectant for bacteria and viruses. Using chlorine dioxide instead of chlorine can assist in reducing the formation of harmful halogenated disinfection byproducts, for example trihalomethanes and halogenated acetic acids. However, using chlorine dioxide for drinking water disinfection can form the by-products chlorite and chlorate which must be monitored. Use of chlorine dioxide shall conform to the publication Chlorine Dioxide.

Ozone is commonly used in drinking water treatment for disinfection as well as taste and odour control. Ozone is a strong oxidant that can inactivate microorganisms, including *Cryptosporidium*, *Giardia*, and viruses, as well as oxidize and break down natural organic matter. Ozone exists as a gas at room temperature and must be generated on-site. Ozone reacts rapidly with organic and inorganic compounds and does not maintain a residual in water for a significant amount of time. Proposed use of ozone requires a safety study including bromate analysis. Designs must comply with the publication Ozone.

Other materials that can act as disinfectants include potassium permanganate, iodine, hydrogen peroxide and ultraviolet (UV) light. One of the most important factors for determining the germicidal efficiency of a particular disinfectant and the adequacy of disinfection is the CT factor. The CT factor is defined as the residual disinfectant concentration (mg/L) multiplied by the contact time (T, min) between the point of disinfectant application and the point of residual measurement.
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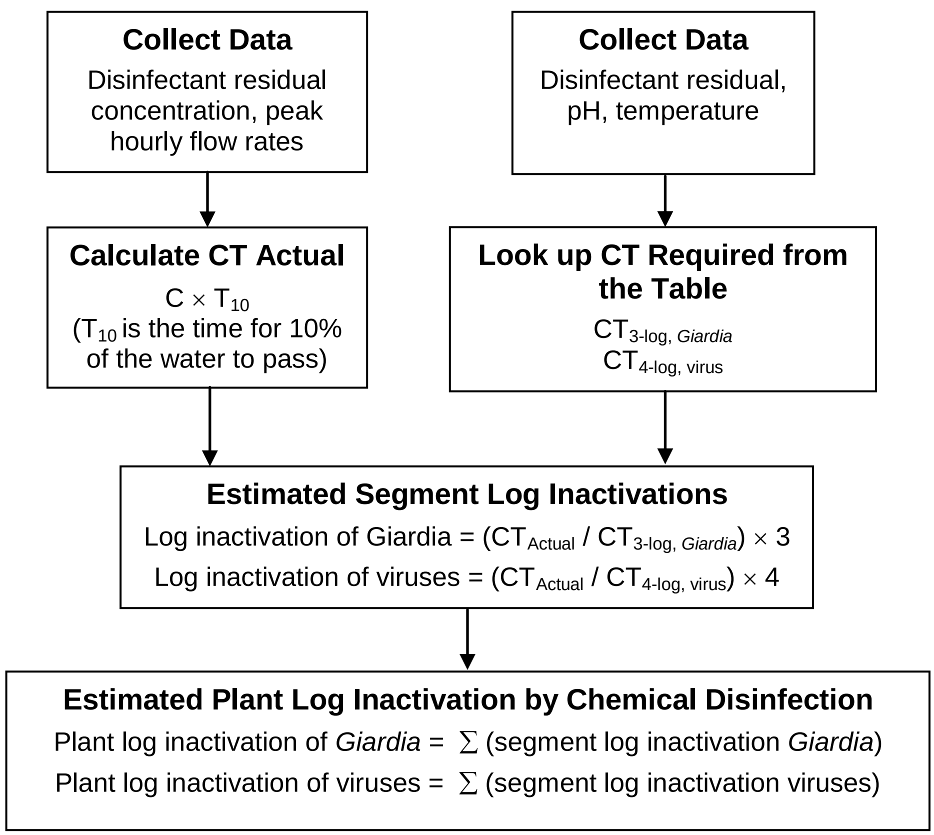


**Figure 3.1 Disinfection profile methodology**

For all water treatment systems, compliance to a specified treatment level must be ascertained by evaluation of CT values. The effective contact time should be determined by tracer studies.

The CT values corresponding to 3-log *Giardia* and 4-log virus inactivations are the basis for determining the estimated log inactivation achieved by the plant on any given day. Operational information required to use the CT tables include: disinfectant type, temperature, pH (for chlorine only) and residual disinfectant concentration. The CT value for a particular disinfectant corresponding to inactivations of 3-logs of Giardia ($CT_{3\text{-log, }\mathit{Giardia}}$) and 4-logs of viruses ($CT_{4\text{-log, virus}}$) can be read from the tables which are shown in Appendix A. These CT values can be used to determine the estimated log inactivation achieved by applying a disinfectant to water. The ability of a water treatment plant to inactivate protozoa and viruses can be determined by constructing a disinfection profile using the CT tables (Appendix A). The data to be used for the construction of disinfection profiles must be representative of the entire treatment plant, from the initial point of disinfectant addition to the entrance to the distribution system to the point of delivery to the first customer. The methodology of disinfection profile is shown in Figure 3.1.

Log removal credits are based on both *treatment equipment* credits and *disinfection* CT credits. All drinking water treatment systems shall have a minimum design disinfectant CT as follows:

- all true groundwater-based (non-GUDI, non-surface water) treatment systems shall have a minimum *disinfectant* CT equivalent to 4-log virus reduction or inactivation; and
- all surface water or GUDI-based treatment systems shall have a minimum *disinfectant* CT equivalent to 0.5 log Giardia and 2-log virus reduction or inactivation.

To perform a full CT calculation, refer to the EPA Disinfection Profiling and Benchmarking Guidance Manual. Note that the data collection and population limits in the manual do not apply to Saskatchewan facilities.

For daily operations at facilities where CT calculations are an ongoing operating requirement, CT may be calculated using actual values for reservoir volume, flow, temperature, pH, chlorine residual and other required factors. However, for design purposes the worst case scenario CT calculation must be used to determine if the system will meet CT requirements at all times. Therefore, conservative or worst case scenario values need to be used – for example multiple calculations such as winter and summer conditions may need to be calculated to determine seasonal worst case scenarios. If a design CT calculation shows that a disinfectant level higher than the currently-regulated minimum is required, then that higher disinfectant level shall become the new minimum level and the facility owner must apply to have the Permit to Operate altered to display the new minimum disinfectant level. Further information and examples regarding CT is in the publication Waterworks System Assessment Questions and Answers Part Two.

Ultraviolet light (UV) is recognized as a disinfection alternative to other disinfectants in drinking water treatment. UV has three spectral bands: 1) 100 to 280 nm (short-wave); 2) 280 to 315 (middle-wave); and 3) 315 to 400 nm (long-wave). Typically, disinfection by UV is carried out by short-wave UV. A secondary disinfectant is required to maintain the necessary residual throughout the distribution system. The effectiveness of a UV disinfection system depends on the characteristics of the water, the intensity of UV radiation, the amount of time the microorganisms are exposed to the radiation and the reactor configuration. Medium-pressure lamps are generally used for large facilities. They have approximately 15 to 20 times the germicidal UV intensity of low-pressure lamps. However, these lamps operate at higher temperatures and with a higher energy consumption rate. UV dose is calculated by intensity times the exposure time in seconds and is expressed as $mW.s/cm^2$ ($mJ/cm^2$). The dose required to disinfect water varies with the quality of water, but generally in the range between 24 and 45 $mW.s/cm^2$ ($mJ/cm^2$). Protozoan parasites, particularly *Giardia* and *Cryptosporodium*, may be more resistant to UV inactivation than other microorganisms. Typically, protozoan parasites require a higher UV dose than that needed for other pathogenic organisms. Advances in microorganism research and UV design and operation allow consideration of lower doses based on results of challenge tests.

### 3.2.12 Instrumentations/Controls

Instrumentation and control systems should be selected on the basis of plant complexity, operating competency and operational needs, the need to control key functions to ensure smooth and continuous plant operation and the ability of the systems to be operated efficiently. Monitoring consideration should be given to:

- continuous monitoring and recording of finished water turbidity and chlorine residuals where feasible;

- raw water temperature, flow and turbidity;
- filter rate of flow, loss of head and effluent turbidity;
- washwater flow;
- clearwell or reservoir levels;
- treated water flow and pressure;
- process sensitive water quality variables;
- indicators, recorders and totalizers appropriate to the process; and
- alarm conditions and means for bringing alarms to the attention of responsible operating staff.

Selection of control systems should include considerations of:

- provision of manual backup systems for all automatic controls;
- maintenance and repair capability;
- the probable conditions that may be encountered and the need for consistent, continuous operation;
- the reliability of primary sensing devices; and
- the use of micro-electronic systems.

## 3.3 Groundwater

### 3.3.1 Processes

Groundwater works shall be designed so that treated water quality meets requirements including those listed in Table 3 and Sections 26, 27, 28, 29, 30 and 31 and all sections of The Waterworks and Sewage Works Regulations and The Environmental Management and Protection Act, 2010, and should meet Saskatchewan Municipal Drinking Water Quality Objectives. Many of the waterworks components that are typically used for groundwater treatment have already been discussed in previous chapters.

### 3.3.2 Pre-Filtration Processes

The selection, dosage ranges and application sequences for chemical pre-treatment shall be based on appropriate treatment studies and assessment with consideration given to potential water quality variability, ease in operation, mixing enhancement and retention/reaction times.
Where either the raw water quality or the treatment process yields significant precipitate or settleable material, sedimentation should be incorporated prior to filtration. Sedimentation basin design should be based on the settleability characteristics and consider sludge removal features.

### 3.3.3 Filtration

In general, a minimum of two filters should be provided, with a design working capacity equal to the plant capacity and each capable of independent operation and backwash. In larger facilities with more than two filters, production capacity shall be at least equal to the maximum day plant capacity with the largest filter removed from service.

Filtration rates shall be based on the quality of the raw water, pre-treatment provided, filter media characteristics, operational surveillance available and plant quality control measures. In general, the filtration rates of 5 m/h (1.67 gpm/ft$^2$) to 12.5 m/h (4.17 gpm/ft$^2$) should be considered. Pressure filters should be limited to between 5 and 12.5 m/h (1.67 to 4.17 gpm/ft$^2$).

Sufficient treated water backwash capability shall be provided to develop the appropriate bed expansion consistent with the water temperature and media characteristics. Except for full depth anthracite filters, backwash rates in the 36 to 45 m/h (12-15 gpm/ft$^2$) range should be achievable. Filter bottoms shall be designed to provide uniform distribution of backwash water and the provision of support media should be based on the nature of the filter bottoms. Porous plate bottoms are not recommended for use with water containing high levels of iron and manganese or which have significant scale forming tendencies.

Filter media shall be durable and meet applicable American Water Works Association (AWWA) specifications. Rapid rate gravity filters shall incorporate features noted in Section 3.2.6.1. Pressure filters shall incorporate features noted in Section 3.2.6.2.

### 3.3.4 Manganese Greensand Filtration

Where manganese greensand is used, consideration for the continuous feed of potassium permanganate ahead of the filter shall include retention time needs, use of other preoxidants and the raw water quality.

Media depths shall be adequate to permit good filtration and oxidation and should be a minimum of 600 mm (24 inches). A minimum 150 mm (6 inches) cap of anthracite media is recommended over manganese greensand. Auxiliary air wash facilities are recommended to assist proper backwashing. Manganese greensand filters should have sample taps at the top and mid-depth points in the media.

In some cases, manganese greensand filtration may be used for arsenic removal from groundwater. However, addition of iron at a suitable ratio to the influent arsenic may be necessary to effectively remove arsenic.

### 3.3.5 Other Common Groundwater Treatment Processes

Sequestration of iron and manganese by polyphosphates or sodium silicates should be limited to waters that only slightly exceed maximum objective levels. Removal of iron and manganese by ion exchange should be limited to special cases only and where the raw water requires minimal treatment.

Treatment using substantial pH adjustment through the addition of acids or caustics shall only be undertaken where proper control, neutralization mechanisms and safety features are available.

Filtration technologies such as iron oxide-coated sand filtration systems for arsenic (both arsenite and arsenate) removal may be applicable to small community groundwater supplies. However, demonstration testing at pilot-scale level is necessary. Membrane processes have shown poor arsenic removal in Saskatchewan. Membrane processes shall incorporate features noted in Section 3.2.9.

Ammonia may be present in groundwater as a result of the degradation of naturally occurring organic matter or man-made sources. Natural ammonia levels in groundwater and surface water are usually below 0.2 mg/L, but many regions throughout the world have high levels of naturally occurring ammonia. Ammonia may also originate from nitrogen-fertilizer application, livestock operations, industrial processes, sewage infiltration, and cement mortar pipe lining. A health based guideline has not been developed for ammonia levels in drinking water. However, the World Health Organization suggests that at a concentration above 1.5 mg/L ammonia can cause odour and taste problems. Ammonia can also compromise disinfection efficiency, increase oxidant demand, cause the failure of filters for the removal of manganese, and corrode copper alloy pipes and fittings. A concern with ammonia in drinking water is nitrification associated with the formation of nitrites and nitrates. Nitrites and nitrates can cause health problems; although, this risk is relatively low in Saskatchewan waterworks because of low operating temperatures most of the year. Another health concern is the formation of chloramines when chlorine is added to water systems.

At present, the Water Security Agency does not establish standards or objectives for ammonia levels in drinking water. The maximum acceptable concentration (MAC) is 45 mg/L (10 mg/L as nitrate nitrogen) for nitrate. Where nitrate and nitrite are determined separately, levels of nitrite shall not exceed 3.2 mg/L (1 mg/L as nitrite-nitrogen). Health Canada sets a MAC of 3 mg/L for total chloramines which is based on a risk evaluation for monochloramine. Ammonia in raw water interferes with the chlorine disinfection process and free chlorine residual maintenance in the distribution system. This is due to the rapid reaction of ammonia with chlorine which impedes the achievement of adequate CT values for the inactivation of microorganisms. Decreased disinfection efficiency as well as taste and odor problems are to be expected if drinking water containing more than 0.2 mg/L of ammonia is chlorinated, as the added chlorine may react with the ammonia and become unavailable for disinfection. More information on ammonia is available in the publication Ammonia in Source Water. Primary disinfection for surface water or GUDI sources shall not be by chloramination.

# 4. Treated Water Storage

## 4.1 General

### 4.1.1 Type of Storage

Treated water storage may be clearwell and/or ground level storage at the treatment plant or elevated or ground level storage in the distribution system. The type(s) of treated water storage shall be selected on the basis of many factors such as serviceability requirements, size of service area, topography, costs, etc. Design of storage shall comply with Section 24 of The Waterworks and Sewage Works Regulations.

### 4.1.2 Location
New storage facilities shall be located to enable reasonable access during all climatic conditions and designed so that they can remain in operation during maximum anticipated flooding. As far as practically possible, areas of poor foundations should be avoided.

### 4.1.3 Protection
All treated water storage reservoirs shall have suitable waterproof roofs or covers that exclude birds, animals, insects and excessive dust. Fencing, locks on access man ways and other necessary precautions shall be provided to prevent trespassing, vandalism and sabotage.

### 4.1.4 Freezing
All treated water storage structures and their appurtenances, especially the riser pipes, overflows and vents shall be designed to prevent freezing which will interfere with proper functioning. Elevated storage shall be provided with facilities for heating and circulating the water.

### 4.1.5 Safety
The safety of employees shall be considered in the design of a storage structure. As a minimum, such matters shall conform to pertinent *Occupational Health and Safety Regulations*. Ladders, ladder guards, balcony railings and safely located entrance hatches shall be provided where applicable. Elevated tanks with riser pipes over 200 mm (8 inches) in diameter shall have protective bars over the riser openings in the tank.

## 4.2 Capacities
### 4.2.1 Sizing
Storage facilities shall have sufficient capacity, as determined by engineering studies, to meet domestic demands, plant operating requirements and where fire protection is provided, fire flow demands.

### 4.2.2 Fire Protection
Compliance with the fire survey requirements of insurers, organizations (i.e. Insurers' Advisory Organization) in terms of fire flow is encouraged. Contact the Fire Commissioners office and other authorities for further details. Consideration may be given to small, relatively minor waterworks without fire protection.

### 4.2.3 Recommended Minimum Storage
For systems requiring fire protection, minimum storage capacity shall be equal to or greater than twice the average daily consumption. For systems not providing fire protection, minimum storage shall be equal to or greater than the average daily consumption.

## 4.3 Design Features
### 4.3.1 General
Materials and designs used for finished water storage structures shall provide stability, durability and water tightness as well as protect the quality of the stored water. Construction products and/or materials shall not adversely affect water quality.

Consideration should be given to miscellaneous design elements such as:
- providing positive water circulation in the reservoir;
- sizing and baffling when storage is used to provide contact time for chlorine;
- providing two cells if economically feasible and/or by-passes to allow flexibility and continuity of service during maintenance periods;
- pump wells in clearwell reservoirs to avoid excessive dead storage; and
- providing proper site drainage and protection against uplift forces.

Roofs, sidewalls and floors shall be watertight with no openings except properly designed vents, man way entrances, overflows, risers, drains, etc.

#### 4.3.2 Materials
Steel structures shall conform to current AWWA standards concerning steel tanks, standpipes, reservoirs and elevated tanks wherever they are applicable. Storage structures constructed of other materials shall conform to applicable industry standards, such as AWWA, CSA, ASTM or CGSB.

#### 4.3.3 Protective Coatings and/or Cathodic Protection
Proper protection should be given to metal surfaces by paints or other protective coatings, by cathodic protection or by both. After proper curing, the coating shall not adversely affect water quality. Cathodic protection shall be designed and installed by competent technical personnel.

#### 4.3.4 Drains and Through-Piping
Drains on a water storage structure shall not have a direct connection to a sewer or a storm drain, and must have appropriate backflow protection. The design would typically allow draining the storage facility for cleaning and maintenance without causing loss of pressure in the distribution system. All pipes that pass through a reservoir shall be constructed and maintained to prevent contaminants from entering the water storage reservoir – minimum protection is to be concreted pipe.

#### 4.3.5 Drainage of Roof
The roof of a storage reservoir shall be well drained. Downspout pipes shall not enter or pass through the reservoir. Parapets, or similar construction, which would tend to hold water and snow on the roof should be avoided, if possible. If parapets, etc. are used, special attention shall be paid to waterproofing and drainage.

#### 4.3.6 Entrances
Finished water storage reservoirs shall be designed with convenient access to the interior for cleaning and maintenance. Manhole entrances above the waterline typically have:

- a solid watertight cover that overlaps the framed opening and extends down around the frame at least 50 mm (2 inches);
- hinging at one side; and
- a locking device.

All manholes providing access to an underground or ground level reservoir shall extend at least 150 millimetres above the grade of the surrounding area and the grade shall be sloped away from the reservoir to prevent flooding by surface run-off. All manholes providing access to a reservoir shall be equipped with a tight-fitting cover designed to prevent entry of water and if the reservoir is located outdoors, be kept locked at all times except when being used by persons authorized by the permittee to enter the reservoir.

#### 4.3.7 Vents
Treated water storage structures shall be vented separate from any overflows. Open construction between the sidewall and roof is not considered acceptable. An opening or pipe used to ventilate a reservoir shall be designed to prevent the entry of birds, rodents, rain water or foreign matter and shall be screened.

Ground level structure vents should typically terminate in an inverted U construction with the opening 600 mm to 900 mm (24 to 36 inches) above the roof or sod and should be covered with twenty-four mesh non-corrodible screen installed within the pipe at a location least susceptible to vandalism.

#### 4.3.8 Cleaning/Disinfection
Finished surfaces and floor slopes shall be designed to facilitate cleaning and disinfection. Treated water storage reservoirs require cleaning and disinfection prior to being placed in service, in accordance with the latest applicable AWWA standard. Construction specifications shall identify an appropriate method of disinfecting and bacteriological sampling/testing. Cleaning and disinfection needs to include the roof of the tank or reservoir, from which condensate may drop back into the water supply. Time restrictions are faced while undergoing reservoir commissioning procedures. The time restrictions and associated requirements are the same as for mains piping as seen in Section 5.3.6. It is essential that involved parties liaise to plan commissioning otherwise the reservoir may not be available before the sample results expire.

### 4.4 Hydropneumatic (Pressure) Tanks

#### 4.4.1 Pressure Tank Storage

Pressure tank storage is acceptable for small water systems but is not to be considered for fire protection purposes. Pressure tanks shall comply with pressure vessel codes and regulations.

#### 4.4.2 Location

Due consideration should be given to proper location, protection from corrosion by elevating tanks above floor levels, adequate sizing, bypass piping and valving to facilitate maintenance, servicing access ports, drain, air blow-off means for adding air and pressure operated start-stop controls for the pumps.

## 5. Distribution

### 5.1 General

Conventional municipal distribution systems, which provide fire protection, are referred to as municipal waterworks. Very small systems, which do not provide fire protection, are referred to as domestic waterworks. Design information on rural pipelines is found in the publication Water Pipeline Design Guidelines.

Design and construction of water distribution systems shall comply with all local or provincial bylaws and regulations. For distribution extensions, the past performance and records of the municipality shall be reviewed to assure compatibility with existing systems.

Wherever usage records exist, water demands and peaking factors based on usage records for the waterworks shall be used for design of distribution systems. When such records do not exist or are unreliable, water demands and peaking factors derived from installations that are similar in terms of climate, locale, size and character of population shall be used.

New distribution systems shall have new pipe and appurtenances. Retrofit distribution installations can use pipe and appurtenances previously used for the same drinking water purposes only if the pipe and appurtenances are known to not be contaminated. Pipe and appurtenances known to be contaminated are not to be used in distribution systems. Pipe and appurtenances previously used to convey sewage cannot be used in water distribution systems under any circumstance. If human bones are encountered during construction, work must stop on the site immediately and the RCMP must be contacted.

Whether or not fire protection is provided via the communal drinking-water system is the decision of the municipality/owner of the system and can be subject to a cost/risk-benefit analysis, especially for smaller systems. However, once the decision has been made to provide fire protection via the communal drinking-water system, the designer shall consult the latest edition of Fire Underwriters Survey document *Water Supply for Public Fire Protection* and the municipality/owner decision respecting fire protection. The designer can refer to AWWA *Manual of Water Supply Practices M31 – Distribution System Requirements for Fire Protection* and *Section 8.4 – Sizing of Storage Facilities* for more information regarding required fire flows. The designer shall also consider local fire flow rates when sizing the pipes. In some cases, it can be necessary to evaluate the provision of separate pipes for fire and potable supplies to maintain water quality.

Water quality deteriorates through interactions between the pipe wall and the water, and reactions within the bulk water itself. Depending on the retention time in the system, water flow, treated water quality, pipe materials and condition and deposited materials (i.e., sand, iron, manganese), the water quality will change to a greater or lesser extent. Therefore, water age, a function of system design, water demand and system operation, is a major factor in water quality deterioration within the distribution system. Systems shall be designed to maximize turnover and to minimize retention times and water age. Careful consideration must be given to distribution main sizing, providing for multidirectional flow, adequate valving for distribution system control and provisions for flushing and occasional “swabbing”. In addition, positive pressure must be maintained at all times to prevent intrusion of contaminants. The designer can consult references such as the AWWARF report *Guidance Manual for Maintaining Water Quality in the Distribution System* (Project #357), 2000 and the USEPA document *Distribution System White Papers*.

Systems must be designed to prevent depressurization which occurs when any disruption causes a loss of continuous positive pressure to below 20 psi. The potential for public health risks associated with depressurized distribution system is directly linked to pathogen contamination, harmful chemical intrusion, and exposure to excess disinfectant residual. For more information see publication System Depressurization.

### 5.1.1 Cross Connection Control

There shall be no physical cross connection between a public or private potable water supply system and a sewer or appurtenance or item thereto, which could permit the passage of any sewage or polluted water or contamination into the water supply. A water outlet or any of its component parts that may come in contact with contamination must be equipped with a backflow prevention device that, in the opinion of the Water Security Agency, is effective. A cross connection is any point in a water system where chemical, biological or radiological contaminants may come into contact with water intended for human consumption or hygienic use. During a backflow event, these contaminants can be drawn or pushed back into the water system. Strict precautions must be taken to prevent the entrance of contaminating materials into the supply of water for hygienic use or human consumption use. The design shall layout backflow prevention devices (BPD) to eliminate cross connection hazards. An example of a cross connection hazard is the backflow of pesticides into drinking water while spray tanks are filled by a customer at a yard hydrant fed by a line experiencing negative pressure. No cooling water shall be returned into the drinking water system. A BPD shall be installed at every point of cross-connection to prevent contaminated water from entering a water system. A cross connection control program is recommended as presented in the publication Cross Connection Control and Backflow Prevention Program Guidelines. Backflow preventers shall be installed in accordance with the latest edition of the Cross Connection Control Manual, published by AWWA (Western Canada Section). Degrees of cross-connection hazard include:

- **Severe** - A cross connection or potential cross connection involving any substance in sufficient concentration to cause death, spread disease or illness or contain any substance which has a high probability of causing such effect. A suitable backflow preventer is an air gap (AG) assembly or a reduced pressure zone (RPZ) device. Moderate and minor hazards are also covered by these devices. Examples of severe cross connection hazards include water loading facilities taking raw water from any part of a drinking water system, drinking water service to a sewage pumping station, or connection of a drinking water system to a chemical solution mixing tank

- **Moderate** - A cross connection or potential cross connection involving any substance which has a low probability of becoming a nuisance or be aesthetically objectionable if introduced into the domestic water supply. A suitable backflow preventer is a double check valve assembly (DCVA) or similar. Examples of moderate cross connection hazards include water loading facilities taking drinking water where tanks used for conveying contaminated substances are not allowed to fill.

- **Minor** - An existing connection or a potential connection between the domestic water pipe and any pipe, vat or tank intended for carrying or holding drinking water which has a low probability of becoming a moderate hazard. A suitable backflow preventer is a dual check valve assembly (DUC).

Backflow prevention devices must be installed at locations that allow routine inspection. Installation of backflow devices in below-grade manholes and similar locations that are prone to flooding is not allowed. The operations plan for a water facility shall include an inspection schedule of all backflow prevention devices.

## 5.2 Pumping Facilities

### 5.2.1 General

Pumping stations shall be designed to be accessible in all weather conditions and located so that the proposed site will meet requirements for sanitary protection of water quality, hydraulics of the system and protection against interruption of service by fire, flood, vandalism or any other hazards.

Pumping stations shall be designed to provide adequate space for the installation of additional units if needed and for the safe servicing of all equipment. Consideration shall be given to providing hoist-beams, crane-ways, floor openings, etc. for servicing and removal of heavy or bulky equipment.

For worker safety, ladders, ladder guards, balcony railings, and equipment to provide worker safety shall be provided and the pertinent *Occupational Health and Safety Act and associated regulations* shall be adhered to.

Pump station buildings shall be properly ventilated, heated and adequate lighting provided in accordance with all local and provincial regulations. Stations, which are staffed for extended periods need to be provided with treated water, lavatory and toilet facilities. Wastes shall be handled so as to prevent contamination of a public water supply.

The floor of every pump house shall be designed so that drainage occurs only into the floor drains or sumps. All pipes that connect the discharge pipe from a treatment component in a pump house to a sanitary sewer shall be equipped with a backflow prevention device that is, in the opinion of the Water Security Agency, effective, as seen in Section 5.1. Every pump house shall be equipped with a meter that records the volume of water passing through the pump house. Every chemical feeder in a pump house is to be equipped with a device that is capable of adjusting the rate of chemical applied. Every pump house is to be maintained in a clean and orderly condition satisfactory to the minister.

### 5.2.2 Pumps

At least two pumping units shall be provided (in addition to any pumps required to provide fire flows). With any one pump out of service, the remaining pump(s) shall be capable of serving the maximum daily pumping demand of the system.

Pumping units shall have ample capacity to supply the peak demand and pressure conditions without dangerous overloading, be driven by prime movers able to operate against maximum head, have spare parts and tools available and be served by control equipment that has proper heater and overload protection for air temperature encountered.

Due consideration needs to be given to such factors as avoiding suction lift, if possible, or maintaining it within allowable limits; priming of pumps and protection of pump station headers against pressure surges.

Booster pumping stations shall contain not less than two pumps with capacities such that peak demand can be satisfied with the largest pump out of service. Consideration shall be given to the provision of standby power generation in the event of power outages.

## 5.3 Distribution Systems

### 5.3.1 Materials

Pipes, fittings, valves, fire hydrants and other appurtenances shall conform to the latest standards issued by AWWA and/or CSA. Materials used for any newly constructed water distribution works or alteration or extension to existing water distribution works shall comply with the latest versions of “NSF/ANSI Standard 61: Drinking Water System Components – Health Effects” and “NSF/ANSI Standard 372: Drinking Water System Components – Lead Content”. Anticipated water quality and bedding soil characteristics shall be considered in selecting pipe materials, which will protect against both internal and external pipe corrosion.

Designs shall accommodate the possible presence of sub-surface contaminants and the potential of such contaminants migrating through mains into the water supply. Where distribution systems are installed in areas of groundwater contaminated by organic compounds, materials which do not allow permeation of the organic compounds shall be used for all portions of the system, including pipe, joint materials, O-rings, gaskets, hydrant leads and service connections (ex. avoid HDPE where gasoline contamination may exist and PVC where dry cleaning solvent may be present).

### 5.3.2 Layout and Placement

Distribution system layouts are usually designed in one of three configurations, including arterial-loop systems, grid systems and tree systems.

Tree systems often have more dead-ends and the selection of this type of layout is generally not recommended. Water distribution systems shall be designed to minimize dead-ends by making appropriate tie-ins or looping whenever practical in order to provide increased reliability of service and reduce stagnation and loss of disinfectant residual. Where dead-end mains cannot be avoided, they shall be provided with a fire hydrant, blow-off or other acceptable measures to prevent problems associated with stagnation. For domestic waterworks, consideration may be given to the use of "yard hydrants" for flushing purposes. No flushing device shall be directly connected to a sewer.

Adequate separation of water mains and sewer mains shall be maintained with due consideration given to such matters as pipe materials, soil conditions, service and connections into the mains. Water mains shall cross above sewers with a sufficient vertical separation to allow for proper bedding and structural support of the water and sewer mains. Designs where water mains cross below sewer mains shall be used only where absolutely necessary and use is to be strictly minimized. Where it is necessary for the water main to cross below the sewer, the water main shall be protected by providing:

- A vertical separation of at least 0.6 m from water main crown to sewer invert;
- Structural support of the sewer to prevent excessive joint deflection and settling; and
- Water main is to be centered at the point of crossing so that the joints are equidistant from the sewer pipe.

No person shall install a water main in a common trench with a sewer main unless at a service connection and only if the sewer pipe is not under internal pressure and is not located above the water pipe. Water mains and sewer mains must be separated by a minimum of 2.5 metres (8 ft) horizontally between the pipes, with the area between the pipes constructed to leave as much ground undisturbed as possible while maintaining safety. Unusual conditions including excessive rock, dewatering problems, or congestion with other utilities may prevent the normal required horizontal separation of 2.5 m. Under these conditions, Water Security Agency approval is needed for a lesser separation distance than 2.5 m, provided also that the crown of the sewer pipe is at least 0.5 m below the water main invert and that the sewer pipe is not under internal pressure. Where extreme conditions prevent the 2.5 m separation and vertical separation cannot be obtained, the sewer shall be constructed of pipe and joint materials which are equivalent to water main standards.

All water mains shall be covered with sufficient earth cover or insulation below finished street/road grades to prevent freezing. With the exception of those water mains which will be taken out of service and drained in winter, the minimum depth of cover over water mains is typically greater than the depth of frost penetration The depth of frost penetration for a location shall be based on the coldest three years during the past 30 years, or, where this period of record is not available, the coldest year during the past 10 years with an appropriate safety factor. As an example, recommended minimum cover above the crown of the pipe is 2.5 m in the warmest geographic areas to over 3.0 m in the coldest areas.

Water main bedding and backfill shall be placed so that the pipe is adequately supported and protected. Fittings and appurtenances shall be provided with reaction blocking as needed to prevent movement.

#### 5.3.3 Sizes, Pressures

All water mains, including those not designed to provide fire protection, shall be sized to ensure adequate pressure and flow at the period of peak demand. Municipal distribution systems shall be sized to meet fire flows and maximum daily demand occurring simultaneously.

The minimum size of mains for municipal waterworks (fire protection provided) shall be 150 mm (6 inches). Sizing of mains for domestic waterworks (no fire protection) must consider hydraulic requirements with due regard to future maintenance requirements such as the potential need for yard hydrants to assist swabbing operations.

Although a 20-year design period is most frequently used for water treatment supply systems, it is required that longer design periods be used based on long-term population projections, given that water distribution systems have useful life expectancies well in excess of 20 years. Consideration shall also be given to water quality deterioration arising from potential oversizing of the initial equipment.

All water mains, including those not designed to provide fire protection, shall be sized after a hydraulic analysis based on flow demands and pressure requirements. The system shall be designed to maintain a minimum pressure of 140 kPa (20 psi) at ground level at all points in the distribution system under maximum day demand plus fire flow conditions. The normal operating pressure in the distribution system can be approximately 350 to 480 kPa (50 to 70 psi) and shall not be less than 275 kPa (40 psi). The designer shall also consider pressure losses within serviced buildings due to the installation of equipment or appurtenances (water meters, backflow preventers, etc.) relative to the minimum operating pressure in the system. The maximum pressures in the distribution system under normal operating conditions shall not exceed 700 kPa (100 psi) to avoid damage to household plumbing and unnecessary water and energy consumption. When static pressures exceed 700 kPa (100 psi), pressure reducing devices are typically provided on mains or service connections in the distribution system.

### 5.3.4 Fire Hydrants (Municipal Waterworks)

Fire hydrants shall be located to provide adequate accessibility for fire-fighting equipment, with due consideration given to type of equipment available, type and density of buildings. Hydrant spacing shall range from 90 m (300 feet) to 180 m (600 feet) depending on the type of area served. Fire hydrants are typically provided at each street intersection, in the middle of long blocks and at the end of long dead-end streets. The required hydrant spacing decreases as the fire flow requirement increases. Hydrants shall, therefore, be placed much closer together in high risk, high density areas, than in low density residential areas. For more detailed information on hydrant spacing, refer to the latest edition of the Fire Underwriters Survey document *Water Supply for Public Fire Protection* and system municipality/owner or municipal requirements.

Fire hydrants typically have a bottom valve size of at least 125 mm (5 inches), one 115 mm (4 ½ inch) pumper nozzle and two 64 mm (2 1/2 inch) nozzles. Fire hydrant leads shall be a minimum of 150 mm (6 inch) diameter. Valving of hydrant leads is recommended but optional.

Fire hydrant drains can be plugged and the barrels pumped dry during freezing weather where the groundwater is permanently above the drain port. Where hydrant drains are not plugged, they can drain to gravel beds or to dry wells provided exclusively for that purpose. Hydrant drains shall not be connected to or located within 3 m (10 feet) of sanitary sewers or storm drains.

Fire hydrants are typically installed only on water mains capable of supplying fire flow requirements.

### 5.3.5 Valves, Appurtenances

Sufficient valves shall be provided on water mains so that inconvenience and sanitary hazards will be minimized during repair operations. The municipality/owner of the system shall be consulted with respect to valve locations at intersections, line valve spacing, types of valves permitted, direction of rotation to open and the maximum size of valve permitted in a valve box. Spacing of valves shall take into consideration the nature of development and future expansion.

A sufficient number of valves shall be provided on water mains to minimize inconvenience and contamination during repairs. Valves typically are located at not more than 150 m (500 ft) intervals in commercial and industrial districts and at not more than one block or 240 m (800 ft) intervals in other districts. In distribution system grid patterns, to minimize disruption during repairs, intersecting water mains are typically equipped with shut-off valves.

Valve positions shall be recorded on plans of record ("as-constructed" drawings) or other such documentation to facilitate their location for repair operations or for adjustments during future paving work.

### 5.3.6 Construction and Maintenance Practices

During installation, pipes and appurtenances shall be as free as possible of all foreign material.
When pipe laying is not in progress, open ends shall be effectively plugged, sealed or covered to prevent the entry of rodents, foreign material or water into the pipe. Water mains shall be pressure tested before the commencement of its use.

Water mains shall be disinfected following construction and proven bacteriologically safe prior to operation. During installation, pipes and appurtenances shall be kept free of foreign material. Pipes shall be flushed prior to chlorination. Pipe disinfection must conform to the latest edition of the “AWWA (American Water Works Association) Standard for Disinfecting Water Mains C651”. For example, new water mains must be chlorinated so that a free chlorine residual of 10 mg/L exists in all sections of the pipe after 24 hours of contact time, or equivalent as seen in the “AWWA Standard for Disinfecting Water Mains C651”. All valves and other appurtenances are typically operated while a pipeline is being chlorinated. After completion of the chlorination process, the chlorinated water in the pipes shall be completely removed by thorough flushing. The chlorinated water must be disposed in an environmentally safe manner. Drinking water distribution pipes shall be pressure tested. The publication Managing Wastes Generated by Water Treatment, Distribution, Maintenance, Repair and Extension contains additional information to be followed for flushing and residual management.

Verification of bacteriological safety shall conform to the latest edition of the “AWWA Standard for Disinfecting Water Mains C651” and **“**EPB 560A Waterwork Start-Up Standard”. New or altered water mains require bacteriological safety verification prior to operation. Two consecutive sets of a minimum of two samples along with turbidity and total chlorine residual data for each sample will be required. The requirement for two samples is a minimum and many projects will require more than two samples for each set, as seen in the C651 AWWA Standard. Sampling will continue until two consecutive sets of all samples meet the regulatory requirements for free or total chlorine residual and turbidity and provide negative bacteriological results. Discharges of water to the environment shall not contain a Total Residual Chlorine exceeding 0.02 mg/L.

Time restrictions are faced while undergoing drinking water mains commissioning procedures. Once a pipe has bacteriological sample sets taken which passed, the pipe must be either connected to the mains system and water must flow for human consumptive use within seven days or the pipe must be flushed within seven days from the sample passing bacterial tests. (Note: The timeline starts at a passed set of bacteriological tests which follow the initial disinfection). If regulated minimum chlorine residual levels are not maintained within the pipe after the sample passes bacterial tests, the pipe must then be flushed by day seven and connected for human consumptive use within a further seven days or it must be re-chlorinated, re-sampled and the time period restarts. The maximum time from successful testing to human consumptive use is to be 14 days (which would include a single flushing at seven days). After that time, re-disinfection and bacteriological re-testing of the water main must be conducted. Note that maintaining regulated chlorine residual levels within the pipe is equivalent to human consumptive use from the pipe; for example if there is minimal contractor use of water or if water is bled or if nothing is done or any other activity displays the ability to meet regulated chlorine levels in the pipeline, then this activity is equivalent to human consumptive use and rechlorination and re-testing is not required. It is essential that owners, designers, contractors and developers liaise to plan commissioning otherwise the connection may not be available before the sample results expire.

### 5.3.7 Water Loading Stations

In cases where water loading stations form part of the system, due consideration shall be given to preventing contamination of either the public supply or treated water vessels being filled. In the design of water loading stations, there shall be no backflow to the public water supply, and the piping arrangement shall prevent contaminants being transferred from one hauling vessel to another, and hoses shall not be contaminated by contact with the ground or any contaminating substance.

For water loading stations where tanks used for conveying contaminated substances are not allowed to fill, and the station is providing water intended or used for drinking, that station shall have a minimum of two signs readily observable by persons approaching and at the station. The minimum signage size is to be 600 mm by 900 mm and the sign is to indicate in large clear lettering that filling of tanks containing deleterious substances (e.g.: agricultural spray tanks) is not allowed. These stations require a minimum Double Check Valve Assembly (DCVA) testable backflow prevention device, or a similar device rated to handle a minimum of Moderate cross-connection hazards, on the fill line. The piping arrangement at the loading station shall prevent contaminants being transferred from one hauling vessel to another, and shall prevent hoses from contamination by contact with the ground or any contaminating substance.

Tanks and vessels used for conveying contaminated substances shall not be allowed to fill at drinking water loading stations. Stations that provide water loading into tanks that carry contamination, including raw water loading stations, that source water from any part of a drinking water system, shall be equipped with a minimum of an Air Gap backflow prevention device, or a similar device rated to handle a Severe cross-connection hazard, to protect the drinking water supply. Stations that provide water loading into tanks that carry contamination, and source water from any part of a drinking water system, shall be equipped with a minimum of two signs readily observable by persons approaching and at the station. The minimum signage size is to be 600 mm by 900 mm and the sign is to indicate in large clear lettering that filling of drinking water tanks is not allowed.

## Appendix A

**Table 1: CT values ($CT_{99.9}$) for 99.9 percent inactivation of *Giardia lamblia* cysts by Free Chlorine at 0.5 $^0$C or lower* (3-log inactivation)**

| Free residual (mg/L) | pH | | | | | | |
|---|---|---|---|---|---|---|---|
| | ≤ 6.0 | 6.5 | 7.0 | 7.5 | 8.0 | 8.5 | ≤ 9.0 |
| ≤ 0.4 | 137 | 163 | 195 | 237 | 277 | 329 | 390 |
| 0.6 | 141 | 168 | 200 | 239 | 286 | 342 | 407 |
| 0.8 | 145 | 172 | 205 | 246 | 295 | 354 | 422 |
| 1.0 | 148 | 176 | 210 | 253 | 304 | 365 | 437 |
| 1.2 | 152 | 180 | 215 | 259 | 313 | 376 | 451 |
| 1.4 | 155 | 184 | 221 | 266 | 321 | 387 | 464 |
| 1.6 | 157 | 189 | 226 | 273 | 329 | 397 | 477 |
| 1.8 | 162 | 193 | 231 | 279 | 338 | 407 | 489 |
| 2.0 | 165 | 197 | 236 | 286 | 346 | 417 | 500 |
| 2.2 | 169 | 201 | 242 | 297 | 353 | 426 | 511 |
| 2.4 | 172 | 205 | 247 | 298 | 361 | 435 | 522 |
| 2.6 | 175 | 209 | 252 | 304 | 368 | 444 | 533 |
| 2.8 | 178 | 213 | 257 | 310 | 375 | 452 | 543 |
| 3.0 | 181 | 217 | 261 | 316 | 382 | 460 | 552 |

**Table 2: CT values ($CT_{99.9}$) for 99.9 percent inactivation of *Giardia lamblia* cysts by Free Chlorine at 5 $^0$C* (3-log inactivation)**

| Free residual (mg/L) | pH | | | | | | |
|---|---|---|---|---|---|---|---|
| | ≤ 6.0 | 6.5 | 7.0 | 7.5 | 8.0 | 8.5 | ≤ 9.0 |
| ≤ 0.4 | 97 | 117 | 139 | 166 | 198 | 236 | 279 |
| 0.6 | 100 | 120 | 143 | 171 | 204 | 244 | 291 |
| 0.8 | 103 | 122 | 146 | 175 | 210 | 252 | 301 |
| 1.0 | 105 | 125 | 149 | 179 | 216 | 260 | 312 |
| 1.2 | 107 | 127 | 152 | 183 | 221 | 267 | 320 |
| 1.4 | 109 | 130 | 155 | 187 | 227 | 274 | 329 |
| 1.6 | 111 | 132 | 158 | 192 | 232 | 281 | 337 |
| 1.8 | 114 | 135 | 162 | 196 | 238 | 287 | 345 |
| 2.0 | 116 | 138 | 165 | 200 | 243 | 294 | 353 |
| 2.2 | 118 | 140 | 169 | 204 | 248 | 300 | 361 |
| 2.4 | 120 | 143 | 172 | 209 | 253 | 306 | 368 |
| 2.6 | 122 | 146 | 175 | 213 | 258 | 312 | 375 |
| 2.8 | 124 | 148 | 178 | 217 | 263 | 318 | 382 |
| 3.0 | 126 | 151 | 182 | 221 | 268 | 324 | 389 |

* These CT values achieve greater than a 99.99 percent inactivation of viruses. CT values between the indicated pH values may be determined by linear interpolation. CT values between the indicated temperatures of different tables may be determined by linear interpolation. If no interpolation is used, use the $CT_{99.9}$ value at the lower temperature and at the higher pH.

**Table 3: CT values ($CT_{99.9}$) for 99.9 percent inactivation of *Giardia lamblia* cysts by Free Chlorine at 10 $^0$C* (3-log inactivation)**

| Free residual (mg/L) | pH | | | | | | |
|---|---|---|---|---|---|---|---|
| | ≤ 6.0 | 6.5 | 7.0 | 7.5 | 8.0 | 8.5 | ≤ 9.0 |
| ≤ 0.4 | 73 | 88 | 104 | 125 | 149 | 177 | 209 |
| 0.6 | 75 | 90 | 107 | 128 | 153 | 183 | 218 |
| 0.8 | 78 | 92 | 110 | 131 | 158 | 189 | 226 |
| 1.0 | 79 | 94 | 112 | 134 | 162 | 195 | 234 |
| 1.2 | 80 | 95 | 114 | 137 | 166 | 200 | 240 |
| 1.4 | 82 | 98 | 116 | 140 | 170 | 206 | 247 |
| 1.6 | 83 | 99 | 119 | 144 | 174 | 211 | 253 |
| 1.8 | 86 | 101 | 122 | 147 | 179 | 215 | 259 |
| 2.0 | 87 | 104 | 124 | 150 | 182 | 221 | 265 |
| 2.2 | 89 | 105 | 127 | 153 | 186 | 225 | 271 |
| 2.4 | 90 | 107 | 129 | 157 | 190 | 230 | 276 |
| 2.6 | 92 | 110 | 131 | 160 | 194 | 234 | 281 |
| 2.8 | 93 | 111 | 134 | 163 | 197 | 239 | 287 |
| 3.0 | 95 | 113 | 137 | 166 | 201 | 243 | 292 |

**Table 4: CT values ($CT_{99.9}$) for 99.9 percent inactivation of *Giardia lamblia* cysts by Free Chlorine at 15 $^0$C* (3-log inactivation)**

| Free residual (mg/L) | pH | | | | | | |
|---|---|---|---|---|---|---|---|
| | ≤ 6.0 | 6.5 | 7.0 | 7.5 | 8.0 | 8.5 | ≤ 9.0 |
| ≤ 0.4 | 49 | 59 | 70 | 83 | 99 | 118 | 140 |
| 0.6 | 50 | 60 | 72 | 86 | 102 | 122 | 146 |
| 0.8 | 52 | 61 | 73 | 88 | 105 | 126 | 151 |
| 1.0 | 53 | 63 | 75 | 90 | 108 | 130 | 156 |
| 1.2 | 54 | 64 | 76 | 92 | 111 | 134 | 160 |
| 1.4 | 55 | 65 | 78 | 94 | 114 | 137 | 165 |
| 1.6 | 56 | 66 | 79 | 96 | 116 | 141 | 169 |
| 1.8 | 57 | 68 | 81 | 98 | 119 | 144 | 173 |
| 2.0 | 58 | 69 | 83 | 100 | 122 | 147 | 177 |
| 2.2 | 59 | 70 | 85 | 102 | 124 | 150 | 181 |
| 2.4 | 60 | 72 | 86 | 105 | 127 | 153 | 184 |
| 2.6 | 61 | 73 | 88 | 107 | 129 | 156 | 188 |
| 2.8 | 62 | 74 | 89 | 109 | 132 | 159 | 191 |
| 3.0 | 63 | 76 | 91 | 111 | 134 | 162 | 195 |

* These CT values achieve greater than a 99.99 percent inactivation of viruses. CT values between the indicated pH values may be determined by linear interpolation. CT values between the indicated temperatures of different tables may be determined by linear interpolation. If no interpolation is used, use the $CT_{99.9}$ value at the lower temperature and at the higher pH.

**Table 5: CT values ($CT_{99.9}$) for 99.9 percent inactivation of *Giardia lamblia* cysts by Free Chlorine at 20 $^0$C* (3-log inactivation)**

| Free residual (mg/L) | pH | | | | | | |
|---|---|---|---|---|---|---|---|
| | ≤ 6.0 | 6.5 | 7.0 | 7.5 | 8.0 | 8.5 | ≤ 9.0 |
| ≤ 0.4 | 36 | 44 | 52 | 62 | 74 | 89 | 105 |
| 0.6 | 38 | 45 | 54 | 64 | 77 | 92 | 109 |
| 0.8 | 39 | 46 | 55 | 66 | 79 | 95 | 113 |
| 1.0 | 39 | 47 | 56 | 67 | 81 | 98 | 117 |
| 1.2 | 40 | 48 | 57 | 69 | 83 | 100 | 120 |
| 1.4 | 41 | 49 | 58 | 70 | 85 | 103 | 123 |
| 1.6 | 42 | 50 | 59 | 72 | 87 | 105 | 126 |
| 1.8 | 43 | 51 | 61 | 74 | 89 | 108 | 129 |
| 2.0 | 44 | 52 | 62 | 75 | 91 | 110 | 132 |
| 2.2 | 44 | 53 | 63 | 77 | 93 | 113 | 135 |
| 2.4 | 45 | 54 | 65 | 78 | 95 | 115 | 138 |
| 2.6 | 46 | 55 | 66 | 80 | 97 | 117 | 141 |
| 2.8 | 47 | 56 | 67 | 81 | 99 | 119 | 143 |
| 3.0 | 47 | 57 | 68 | 83 | 101 | 122 | 146 |

**Table 6: CT values ($CT_{99.9}$) for 99.9 percent inactivation of *Giardia lamblia* cysts by Free Chlorine at 25 $^0$C* (3-log inactivation)**

| Free residual (mg/L) | PH | | | | | | |
|---|---|---|---|---|---|---|---|
| | **≤ 6.0** | **6.5** | **7.0** | **7.5** | **8.0** | **8.5** | **≤ 9.0** |
| ≤ 0.4 | 24 | 29 | 35 | 42 | 50 | 59 | 70 |
| 0.6 | 25 | 30 | 36 | 43 | 51 | 61 | 73 |
| 0.8 | 26 | 31 | 37 | 44 | 53 | 63 | 75 |
| 1.0 | 26 | 31 | 37 | 45 | 54 | 65 | 78 |
| 1.2 | 27 | 32 | 38 | 46 | 55 | 67 | 80 |
| 1.4 | 27 | 33 | 39 | 47 | 57 | 69 | 82 |
| 1.6 | 28 | 33 | 40 | 48 | 58 | 70 | 84 |
| 1.8 | 29 | 34 | 41 | 49 | 60 | 72 | 86 |
| 2.0 | 29 | 35 | 41 | 50 | 61 | 74 | 88 |
| 2.2 | 30 | 35 | 42 | 51 | 62 | 75 | 90 |
| 2.4 | 30 | 36 | 43 | 52 | 63 | 77 | 92 |
| 2.6 | 31 | 37 | 44 | 53 | 65 | 78 | 94 |
| 2.8 | 31 | 37 | 45 | 54 | 66 | 80 | 96 |
| 3.0 | 32 | 38 | 46 | 55 | 67 | 81 | 97 |

* These CT values achieve greater than a 99.99 percent inactivation of viruses. CT values between the indicated pH values may be determined by linear interpolation. CT values between the indicated temperatures of different tables may be determined by linear interpolation. If no interpolation is used, use the $CT_{99.9}$ value at the lower temperature and at the higher pH.

**Table 7: CT values for inactivation of viruses by Free Chlorine, pH 6.0 – 9.0**

| Temperature ($^0$C) | Inactivation (log) | |
|---|---|---|
| | **3** | **4** |
| 0.5 | 9.0 | 12.0 |
| 1 | 8.7 | 11.6 |
| 2 | 8.0 | 10.7 |
| 3 | 7.3 | 9.8 |
| 4 | 6.7 | 8.9 |
| 5 | 6.0 | 8.0 |
| 6 | 5.6 | 7.6 |
| 7 | 5.2 | 7.2 |
| 8 | 4.8 | 6.8 |
| 9 | 4.4 | 6.4 |
| 10 | 4.0 | 6.0 |
| 11 | 3.8 | 5.6 |
| 12 | 3.6 | 5.2 |
| 13 | 3.4 | 4.8 |
| 14 | 3.2 | 4.4 |
| 15 | 3.0 | 4.0 |
| 16 | 2.8 | 3.8 |
| 17 | 2.6 | 3.6 |
| 18 | 2.4 | 3.4 |
| 19 | 2.2 | 3.2 |
| 20 | 2.0 | 3.0 |
| 21 | 1.8 | 2.8 |
| 22 | 1.6 | 2.6 |
| 23 | 1.4 | 2.4 |
| 24 | 1.2 | 2.2 |
| 25 | 1.0 | 2.0 |

**Table 8: CT values for inactivation of *Giardia* cysts by Chlorine dioxide, pH 6.0–9.0**

| Temperature ($^0C$) | Inactivation (log) | |
|---|---|---|
| | **2.5** | **3** |
| 1 | 52.0 | 63.0 |
| 2 | 44.5 | 53.8 |
| 3 | 37.0 | 44.5 |
| 4 | 29.5 | 35.3 |
| 5 | 22.0 | 26.0 |
| 6 | 21.4 | 25.4 |
| 7 | 20.8 | 24.8 |
| 8 | 20.2 | 24.2 |
| 9 | 19.6 | 23.6 |
| 10 | 19.0 | 23.0 |
| 11 | 18.4 | 22.2 |
| 12 | 17.8 | 21.4 |
| 13 | 17.2 | 20.6 |
| 14 | 16.6 | 19.8 |
| 15 | 16.0 | 19.0 |
| 16 | 15.4 | 18.2 |
| 17 | 14.8 | 17.4 |
| 18 | 14.2 | 16.6 |
| 19 | 13.6 | 15.8 |
| 20 | 13.0 | 15.0 |
| 21 | 12.2 | 14.2 |
| 22 | 11.4 | 13.4 |
| 23 | 10.6 | 12.6 |
| 24 | 9.8 | 11.8 |
| 25 | 9.0 | 11.0 |

**Table 9: CT values for Viruses Inactivation by Chlorine dioxide, pH 6.0 – 9.0**

| Temperature ($^0C$) | Inactivation (log) | |
|---|---|---|
| | **3** | **4** |
| 1 | 25.6 | 50.1 |
| 2 | 23.5 | 45.9 |
| 3 | 21.4 | 41.8 |
| 4 | 19.2 | 37.6 |
| 5 | 17.1 | 33.4 |
| 6 | 16.2 | 31.7 |
| 7 | 15.4 | 30.1 |
| 8 | 14.5 | 28.4 |
| 9 | 13.7 | 26.8 |
| 10 | 12.8 | 25.1 |
| 11 | 12.0 | 23.4 |
| 12 | 11.1 | 21.7 |
| 13 | 10.3 | 20.1 |
| 14 | 9.4 | 18.4 |
| 15 | 8.6 | 16.7 |
| 16 | 8.2 | 15.9 |
| 17 | 7.7 | 15.0 |
| 18 | 7.3 | 14.2 |
| 19 | 6.8 | 13.3 |
| 20 | 6.4 | 12.5 |
| 21 | 6.0 | 11.7 |
| 22 | 5.6 | 10.9 |
| 23 | 5.1 | 10.0 |
| 24 | 4.7 | 9.2 |
| 25 | 4.3 | 8.4 |

**Table 10: CT values for inactivation of *Giardia* cysts by Chloramine, pH 6.0 – 9.0**

| Temperature ($^0$C) | Inactivation (log) | |
|---|---|---|
| | 2.5 | 3 |
| 1 | 3,170 | 3,800 |
| 2 | 2,835 | 3,400 |
| 3 | 2,500 | 3,000 |
| 4 | 2,165 | 2,600 |
| 5 | 1,830 | 2,200 |
| 6 | 1,772 | 2,130 |
| 7 | 1,714 | 2,060 |
| 8 | 1,656 | 1,990 |
| 9 | 1,598 | 1,920 |
| 10 | 1,540 | 1,850 |
| 11 | 1,482 | 1,780 |
| 12 | 1,424 | 1,710 |
| 13 | 1,366 | 1,640 |
| 14 | 1,308 | 1,570 |
| 15 | 1,250 | 1,500 |
| 16 | 1,183 | 1,420 |
| 17 | 1,116 | 1,340 |
| 18 | 1,049 | 1,260 |
| 19 | 982 | 1,180 |
| 20 | 915 | 1,100 |
| 21 | 857 | 1,030 |
| 22 | 799 | 960 |
| 23 | 741 | 890 |
| 24 | 683 | 820 |
| 25 | 625 | 750 |

**Table 11: CT values for inactivation of viruses by Chloramine, pH 6.0 – 9.0**

| Temperature ($^0$C) | Inactivation (log) | |
|---|---|---|
| | 3 | 4 |
| 1 | 2,063 | 2,883 |
| 2 | 1,903 | 2,659 |
| 3 | 1,743 | 2,436 |
| 4 | 1,583 | 2,212 |
| 5 | 1,423 | 1,988 |
| 6 | 1,352 | 1,889 |
| 7 | 1,281 | 1,789 |
| 8 | 1,209 | 1,690 |
| 9 | 1,138 | 1,590 |
| 10 | 1,067 | 1,491 |
| 11 | 996 | 1,392 |
| 12 | 925 | 1,292 |
| 13 | 854 | 1,193 |
| 14 | 783 | 1,093 |
| 15 | 712 | 994 |
| 16 | 676 | 944 |
| 17 | 641 | 895 |
| 18 | 605 | 845 |
| 19 | 570 | 796 |
| 20 | 534 | 746 |
| 21 | 498 | 696 |
| 22 | 463 | 646 |
| 23 | 427 | 597 |
| 24 | 392 | 547 |
| 25 | 356 | 497 |

**Table 12: CT values for inactivation of *Giardia* cysts by Ozone**

| Temperature ($^0$C) | Inactivation (log) | |
|---|---|---|
| | **2.5** | **3** |
| 1 | 2.40 | 2.90 |
| 2 | 2.20 | 2.65 |
| 3 | 2.00 | 2.40 |
| 4 | 1.80 | 2.15 |
| 5 | 1.60 | 1.90 |
| 6 | 1.52 | 1.81 |
| 7 | 1.44 | 1.71 |
| 8 | 1.36 | 1.62 |
| 9 | 1.28 | 1.52 |
| 10 | 1.20 | 1.43 |
| 11 | 1.12 | 1.33 |
| 12 | 1.04 | 1.24 |
| 13 | 0.95 | 1.14 |
| 14 | 0.87 | 1.05 |
| 15 | 0.79 | 0.95 |
| 16 | 0.75 | 0.90 |
| 17 | 0.71 | 0.86 |
| 18 | 0.68 | 0.81 |
| 19 | 0.64 | 0.77 |
| 20 | 0.60 | 0.72 |
| 21 | 0.56 | 0.67 |
| 22 | 0.52 | 0.62 |
| 23 | 0.48 | 0.58 |
| 24 | 0.44 | 0.53 |
| 25 | 0.40 | 0.48 |

**Table 13: CT values for inactivation of viruses by Ozone**

| Temperature ($^0$C) | Inactivation (log) | |
|---|---|---|
| | **3** | **4** |
| 1 | 1.40 | 1.80 |
| 2 | 1.28 | 1.65 |
| 3 | 1.15 | 1.50 |
| 4 | 1.03 | 1.35 |
| 5 | 0.90 | 1.20 |
| 6 | 0.88 | 1.16 |
| 7 | 0.86 | 1.12 |
| 8 | 0.84 | 1.08 |
| 9 | 0.82 | 1.04 |
| 10 | 0.80 | 1.00 |
| 11 | 0.74 | 0.92 |
| 12 | 0.68 | 0.84 |
| 13 | 0.62 | 0.76 |
| 14 | 0.56 | 0.68 |
| 15 | 0.50 | 0.60 |
| 16 | 0.48 | 0.58 |
| 17 | 0.46 | 0.56 |
| 18 | 0.44 | 0.54 |
| 19 | 0.42 | 0.52 |
| 20 | 0.40 | 0.50 |
| 21 | 0.37 | 0.46 |
| 22 | 0.34 | 0.42 |
| 23 | 0.31 | 0.38 |
| 24 | 0.28 | 0.34 |
| 25 | 0.25 | 0.30 |

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## Glossary of Symbols and Abbreviations

**Waterworks Abbreviations**

| | |
|---|---|
| ASTM | American Society for Testing and Materials |
| AWWA | American Water Works Association |
| CGSB | Canadian General Standards Board |
| CSA | Canadian Standards Association |
| CT | the residual disinfectant concentration (mg/L) multiplied by the contact time (T, min) between the point of disinfectant application and the point of residual measurement. |
| DPBs | Disinfection By-Products |
| ED | Electrodialysis |
| EDR | Elctrodialysis Reversal |
| GAC | Granular Activated Carbon |
| MF | Microfiltration |
| NF | Nanofiltration |
| PAC | Powdered Activated Carbon |
| RO | Reverse osmosis |
| THMs | Trihalomethanes |
| TOC | Total Organic Carbon |
| UF | Ultrafiltration |
| UV | Ultraviolet |
| d | day |
| ft | feet |
| $ft^2$ | square feet |
| ft/min - | feet per minute |
| fps | feet per second |
| G | flocculation energy gradient |
| gpd | gallons per day |
| gpm | gallons per minute |
| $gpm/ft^2$ | gallons per minute per square foot |
| in | inch |
| L/s | litres per second |
| m | metre |
| $m^2$ | square metre |
| $m^3$ | cubic metre |
| $m^3/d$ | cubic metre per day |
| mgd | million gallons per day |
| mg/L | milligrams per litre |
| m/h | metres per hour ($m^3/h$ per $m^2$) |
| mm | millimetre |
| m/min | metres per minute |
| m/s | metres per second |
| $sec^{-1}$ | per second |