Section 3 – Water Works

3. Water Works

3.1. General

The Engineer should confer with the DOEC before proceeding with the design of any water works. Certain basic requirements are mandatory and others shall be considered to be good practice.

A Technical Report prepared and signed by the Engineer representing the Owner must be submitted to the DOEC. The Technical Report is to be completed in accordance with Section 2 of this Document.

3.1.1. Plant Layout

The following items should be considered with regards to plant layout:

1. Functional aspects of the plant layout,
2. Provisions for future plant expansion,
3. Provisions for expansion of the plant's waste treatment and disposal facilities,
4. Access roads,
5. Site grading,
6. Site drainage,
7. Walks,
8. Driveways, and
9. Chemical delivery.

3.1.2. Building Layout

Design of the building shall provide for:

1. Adequate ventilation, lighting, heating, and drainage,
2. Dehumidification equipment, if needed,
3. Accessibility of equipment for operation, servicing and removal/replacement,
4. Flexibility of operation,
5. Operator and visitor safety,
6. Convenience of operation, and
7. Separation of chemical storage and feed equipment areas to reduce hazards and dust problems.

3.1.3. Location of Structures

Structures shall not be located in areas subject to flooding nor shall impede normal or flood stream flows.

3.1.4. Electrical Controls

Main switch and electrical control gear shall be located above grade, in areas not subject to flooding. Surge protection should be provided.

3.1.5. Standby Power

Dedicated auxiliary standby power shall be required so that the water may be treated and/or pumped to the distribution system during power outages to meet at least the average day demand.

3.1.6. Shop Space and Storage

Shop space and storage consistent with the facilities as designed shall be provided.

3.1.7. Laboratory Equipment

Laboratory equipment and facilities shall be selected and designed to complete in-plant analysis and routine laboratory testing as may be determined by the quality of the raw water source, the complexity of the treatment process, and the extent of the water distribution system involved. The design engineer shall confer with the DOEC on the type and acceptability of testing equipment required. Methods for verifying adequate quality assurances and for routine calibration of equipment shall be provided. Chemical and physical guidelines as specified in the latest version of the *Guidelines for Canadian Drinking Water Quality* (*GCDWQ*) shall be considered as objectives, which are applicable to the Province of Newfoundland and Labrador. The *GCDWQ* note that the maximum acceptable concentration (MAC) can be achieved by available water treatment methods at reasonable cost and it must also be reliably measurable by available analytical methods. If it is determined that water quality criteria are exceeded, priority should be given to meeting the *GCDWQ* objectives taking into account costs, the degree of exceedance and local factors. Accredited testing laboratories shall be used for spatial chemical and physical analysis of both raw and treated water as may be conducted or as directed by the DOEC. Any in-house testing shall be in accordance with Standard Methods for the examination of water and wastewater, or any approved alternative methods.

Sufficient bench space, adequate ventilation and lighting, storage room, laboratory sink, auxiliary facilities, and any other testing equipment as required by the DOEC shall be provided. Air conditioning may be necessary.

3.1.8. Monitoring Equipment

Water treatment plants shall be provided with continuous monitoring equipment such as Supervisory Control and Data Acquisition (SCADA) equipment to monitor water being discharged to the distribution system as follows:

1. Plants treating surface water and plants using lime for softening should have the capability to monitor the parameters to evaluate adequate CT disinfection including turbidity, pH, temperature, and free chlorine residual; and

2. Plants treating groundwater using iron removal and/or iron exchange softening should have the capability to monitor and record free chlorine residual.

3.1.9. Sample Taps

Sample taps shall be provided so that water samples can be obtained from each water source and from appropriate locations in each unit operation of treatment. Taps shall be consistent with sampling needs and shall not be of the petcock type. Taps used for obtaining samples for bacteriological analysis shall be of the smooth-nosed type without interior or exterior threads, shall not be of the mixing type, and shall not have a screen, aerator, or other such appurtenance.

3.1.10. Facility Water Supply

The facility water supply service line and the plant finished water sample tap shall be supplied from a source of finished water at a point where all chemicals have been thoroughly mixed, and the required disinfectant contact time has been achieved. There shall be no cross-connections between the facility water supply service line and any piping, troughs, tanks, or other treatment units containing wastewater, treatment chemicals, raw, or partially treated water.

3.1.11. Wall Castings

Extra wall castings should be built into the structure to facilitate future uses whenever pipe passes through walls of concrete structures.

3.1.12. Meters

All water supplies and treatment facilities shall have an acceptable means of metering the finished water. Electronic data loggers that record and store data as well as totalled flow data are recommended.

3.1.13. Piping Colour Code

To facilitate identification of piping in plants and pumping stations, it is recommended that the colour schemes outlined in Tables 3.1, 3.2, 3.3, and 3.4 be utilized:

3.1.13.1. Water Lines

Table 3.1
Piping Colour Code for Water Lines

Line Contents	Colour
Raw	Olive Green
Settled or Clarified	Aqua
Finished or Portable	Dark Blue

3.1.13.2. Chemical Lines

Table 3.2
Piping Colour Code for Chemical Lines

Line Contents	Colour
Alum or Primary Coagulant	Orange
Ammonia	White
Carbon Slurry	Black
Chlorine (Gas and Solution)	Yellow
Fluoride	Light Blue With Red Band
Lime Slurry	Light Green
Ozone	Yellow with Orange Band
Phosphate Compounds	Light Green with Red Band
Polymers or Coagulant Aids	Orange with Green Band
Potassium Permanganate	Violet
Soda Ash	Light Green with Orange Band
Sulphuric Acid	Yellow with Red Band
Sulphur Dioxide	Light Green With Yellow Band

3.1.13.3. Waste Lines

Table 3.3
Piping Colour Code for Waste Lines

Line Contents	Colour
Backwash Waste	Light Brown
Sludge	Dark Brown
Sewer (Sanitary or Other)	Dark Gray

3.1.13.4. Other

Table 3.4
Piping Colour Code for Other Types of Lines

Line Contents	Colour
Compressed Air	Dark Green
Gas	Red
Other Lines	Light Gray

In situations where two colours do not have sufficient contrast to easily differentiate between them, a 150 mm band of contrasting colour should be painted on one of the pipes at approximately 1-metre intervals. The name of the liquid or gas should also be painted on the pipe. In some cases it may be advantageous to paint arrows indicating the direction of flow.

3.1.14. Disinfection

All wells, pipes, tanks, and equipment, which can convey or store potable water, shall be disinfected in accordance with the latest applicable AWWA standards. Plans or specifications shall outline the procedure, and include the disinfectant dosage, contact time, and method of testing the results of the procedure.

3.1.15. Operation and Maintenance Manuals and Parts Lists

An operation and maintenance manual including a parts list and parts order form, operator safety procedures and an operational trouble-shooting section shall be supplied to the water works as part of any proprietary unit installed in the facility.

3.1.16. Operator Instruction

Provisions shall be made for operator instruction at the start-up of a plant or pumping station and follow-up review and additional instruction after a period of 3 months of operation.

3.1.17. Other Considerations

Consideration must be given to the design requirements of other federal, provincial, and local regulatory agencies for items such as safety requirements, special designs for the physically challenged, national building code including national plumbing and electrical codes, construction in flood plains, etc.

3.2 Source Development

In selecting the source of water to be developed, the design engineer must prove to the satisfaction of the DOEC that an adequate quantity of water will be available, and that the water which is to be delivered to the consumers will meet the current requirements of the DOEC with respect to microbiological, physical, chemical and radiological qualities. Each water supply should take its raw water from the best available source, which is economically reasonable and technically possible.

3.2.1. Environmental Assessment Process for Source Development

For new public water supplies, and environmental assessment review may be required for projects where:

1. The supply or works is on a schedule salmon river under the *Fisheries Act*;

2. Inter-basin or intra-basin transfers occur; or

3. Construction of roads. Electric power transmission lines or trunk pipelines for the transmission of water will be located more than 500 m from an existing right of way.

The Environmental Assessment Division of the DOEC should be contacted for additional information or guidance.

3.2.2. Control of Organic Contamination for Public Water Supplies

Although standards and advisories for organics are being developed, there have been numerous cases of organic contamination of public water supply sources. In all cases, public exposure to organic contamination must be minimized. There is insufficient experience to establish design standards, which would apply to all situations. Controlling organic contamination is an area of design that requires pilot studies and early consultation with the DOEC. Where treatment is proposed, best available technology shall be provided to reduce organic contaminants to the lowest practical levels. Operations and monitoring must also be considered in selecting the best alternative. The following alternatives may be applicable:

1. Alternate Source Development;

2. Existing Treatment Modifications;

3. Air Stripping For Volatile Organics (refer to Section 3.3.4.5); and

4. Granular Activated Carbon - Consideration should be given to:
   a. Using contact units rather than replacing portion of existing filter media;

   b. Series and parallel flow piping configurations to minimize the effect of break through without reliance on continuous monitoring;

   c. Providing at least two units. Where only two units are provided, each shall be capable of meeting the plant design capacity (normally the projected maximum daily demand) at the approved rate. Where more than two units are provided, the contactors shall be capable of meeting the design capacity at the approved rate with one or more (as determined in conjunction with the DOEC) units removed from service;

   d. Virgin carbon is the preferred media. Although reactivated carbon may eventually present an economic advantage at large water treatment plants, such an alternative may be pursued only with the preliminary endorsement of the DOEC. Regenerated carbon using only carbon previously used for potable water treatment can be used for this purpose. Transportation and regeneration facilities must not have been used for carbon put to any other use; and

e. Acceptable means of spent carbon disposal.

Except for temporary, emergency treatment conditions, particular attention should be given to developing a Technical Report, which, in addition to the normal determinations, includes the following:

1. For organics contaminants found in surface water sources:
   a. Type of organic chemicals, sources, concentration, frequency of occurrence, water pollution abatement schedule, etc.;

   b. Possible existing treatment plant modifications to lower organic chemical levels. Results of bench, pilot or full scale testing demonstrating treatment alternative, effectiveness and costs; and

   c. A determination of the quality and/or operational parameters which serve as the best measurement of treatment performance, and a corresponding monitoring and process control program.

2. For organic contamination found in groundwater sources:
   a. Types of organic chemicals, sources, concentration, estimate of residence time with the aquifer, plume delineation, flow characteristics, water pollution abatement schedule, etc.;

   b. Results of bench or pilot studies demonstrating treatment alternative, effectiveness, and costs;

   c. A determination of the quality and/or operational parameters which serve as the best measure of treatment performance, and a corresponding monitoring and process control program; and

   d. Development and implementation of a wellhead protection plan.

The collection of this type of data is often complicated and lengthy. Permanent engineering solutions will take a significant time to develop. The cost of organic analyses and the availability of acceptable laboratories may further complicate both pilot work and actual operation.

Alternative source development or purchase of water from nearby unaffected systems may be a more expedient solution for contaminated groundwater sources.

3.2.3. Surface Water

A surface water source includes all tributary streams and drainage basins, natural lakes and artificial reservoirs or impoundments above the point of water supply intake. A source water protection plan for continued protection of the watershed from potential sources of contamination shall be provided as determined by the DOEC.

3.2.3.1. Surface Water Quantity Assessment

A surface water quantity assessment should include a review of the available yield of the water supply. The surface water quantity assessment should demonstrate that:

1. Where possible, a minimum drought return period of one in fifty years has been used for calculating the safe yield;

2. A minimum drought duration of 30 days has been used;

3. The yield is adequate to provide ample water for other legal users of the source including any required fish flows;

4. The yield is adequate to meet the maximum current and future water demand including any required fish flows without significantly affecting the watercourse habitat downstream of the intake; and

5. Only live storage has been used in the yield calculations.

Where site-specific stream flow data is available, yield can be estimated by generated mass flow curves. The stream flow data should also be used to estimate the minimum perennial yield on record and to estimate a drought return period for that year.

Where site-specific stream flow data is not available but precipitation data is available a stream flow record may be simulated to generate mass flow curves. In doing so the runoff characteristics should adequately reflect the hydrologic and topographic characteristics of the watershed.

Where both site-specific stream flow and precipitation data exists both methods should be used and compared. The more conservative yield should be adopted.

For sites where neither site-specific stream flow data nor precipitation data exists, a variety of methods should be used to assess available yield of the water supply, and include the following:

1. The WRMD publication "A Guide to Storage –Yield analysis at Ungauged River Sites" and its accompanying spreadsheet can be used to provide a preliminary estimate of storage requirements for a desired yield; and

2. The WRMD publication "Estimation of Low Flows for the Island of Newfoundland: A User's Guide" and its accompanying spreadsheet can be used to provide an estimate of low flows.

3.2.3.2. Quality

A sanitary survey and study shall be made of the factors, both natural and man made, which will affect quality. Such survey and study shall include, but not be limited to:

1. Determining possible future uses of impoundments or reservoirs;
2. Determining degree of control of watershed by owner;
3. Assessing degree of hazard to the supply by accidental spillage of materials that may be toxic, harmful or detrimental to treatment processes;
4. Assessing all waste discharges (point source and non-point sources) and activities that could impact the water supply. The location of each waste discharge shall be shown on a scale map;
5. Obtaining samples over a sufficient period of time to assess the microbiological, physical, chemical and radiological characteristics of the water;
6. Assessing the capability of the proposed treatment process to reduce contaminants to conform to the latest version of the *GCDWQ*; and
7. Consideration of currents, wind and ice conditions, and the effect of confluencing streams.

3.2.3.3. Minimum Treatment

1. The design of the water treatment plant must consider the worst conditions that may exist during the life of the facility.
2. The minimum treatment required shall be determined by the DOEC.
3. Filtration preceded by appropriate pretreatment shall be provided for all surface waters. The DOEC, on a case-by-case basis, may approve exemptions.

3.2.3.4. Design of Intake Structures

Design of intake structures shall provide for:

1. Withdrawal of water from more than one level if quality varies with depth;
2. The conduit and the intake structure should be designed so that the intake ports to the pumps do not draw air. The intake pipe should be laid on a continually rising or falling grade to avoid accumulation of air or gas;
3. Separate facilities for release of less desirable water held in storage;
4. Where frazil ice may be a problem, holding the velocity of flow into the intake structure to a minimum, generally not to exceed 150 mm per second;

5. Intake should have adequate protection against clogging by sediment, debris or ice, flotation and wind and wave pressure;

6. Occasional cleaning of the intake line;

7. Adequate protection against rupture by dragging anchors, ice, etc.;

8. Ports located above the bottom of the stream, lake or impoundment, but at sufficient depth to be kept submerged at low water levels;

9. Where shore wells are not provided, a diversion device capable of keeping large quantities of fish or debris from entering an intake structure;

10. Where necessary, provisions shall be made in the intake structure, in consultation with the DOEC, to control the influx of zebra mussels or other aquatic nuisances.

11. When buried surface water collectors or intake galleries are used, sufficient intake opening area must be provided to minimize inlet headloss. Particular attention should be given to the selection of backfill material in relation to the collector pipe slot size and gradation of the native material over the collector system.

3.2.3.5. Wet Wells

Wet wells shall:

1. Have motors and electrical controls located above grade, and protected from flooding or as may be required by the DOEC;

2. Be accessible;

3. Be designed against floatation;

4. Be equipped with removable or traveling screens before the pipe suction well;

5. Provide for introduction of chlorine or other chemicals in the raw water transmission main, if necessary for quality control;

6. Have intake valves and provisions for backflushing or cleaning by a mechanical device and testing for leaks, where practical; and

7. Have provisions for withstanding surges where necessary.

3.2.3.6. Upground Reservoir

An upground reservoir is a facility into which water is pumped during periods of good quality and high stream flow for future release to treatment facilities. Upground reservoirs shall be constructed to assure that:

1. Water quality is protected by controlling runoff into the reservoir;

2. Dikes are structurally sound and protected against wave action and erosion;

3. Intake structures and devices meet requirements of Section 3.2.3.4;

4. Point of influent flow is separated from the point of withdrawal; and

5. Separate pipes are provided for influent to and effluent from the reservoir.

3.2.3.7. Impoundments and Reservoirs

3.2.3.7.1. Site Preparation

Site preparation shall provide, where applicable:

1. Removal of brush and trees to high water elevation;

2. Protection from floods during construction; and

3. Abandonment of all wells, which will be inundated, in accordance with requirements of the DOEC.

3.2.3.7.2. Construction

Construction may require:

1. Approval from the appropriate regulatory agencies of the safety features for stability and spillway design; and

2. A permit from the DOEC for controlling stream flow or installing a structure on the bed of a stream or waterway.

3.2.4. Groundwater

A groundwater source includes all water obtained from dug, drilled, bored or driven wells, and infiltration lines.

3.2.4.1. Quantity

1. The total developed groundwater source capacity should equal or exceed the design maximum day demand and equal or exceed the design average day demand with the largest producing well out of service.

2. A minimum of two groundwater wells shall be provided.

3. The pump is to be set at the predetermined drawdown level.

3.2.4.2. Auxiliary Power

1. When power failure would result in cessation of minimum essential service, sufficient power should be provided to meet average day demand through:
   a. Connection to at least two independent public sources; or

   b. Portable or in-place auxiliary power.

2. When automatic pre-lubrication of pump bearings is necessary and an auxiliary power supply is provided, the pre-lubrication line should be provided with a valved bypass around the automatic control, or the automatic control shall be wired to the emergency power source.

3.2.4.3. Quality

3.2.4.3.1. Microbiological Quality

After disinfection of each new, modified or reconstructed groundwater source, one or more water samples shall be submitted to a laboratory approved by the DOEC. Microbiological, physical and chemical analysis shall be completed with satisfactory results reported to the DOEC prior to the well being placed into service.

3.2.4.3.2. Physical and Chemical Quality

1. Every new, modified or reconditioned groundwater source shall be examined for applicable physical and chemical characteristics by tests of a representative sample in a laboratory satisfactory to the DOEC, with the results reported to the DOEC.

2. Samples shall be collected at the conclusion of the test pumping procedure and examined as soon as practical.

3. Field determinations of physical and chemical constituents or special sampling procedures may be required by the DOEC.

3.2.4.4. Protection Management

3.2.4.4.1. Well Location

The DOEC shall be consulted prior to design and construction regarding a proposed well location as it relates to required separation between existing and potential sources of contamination and groundwater development. The well location should be selected to minimize the impact on other wells and other water resources.

3.2.4.4.2. Continued Sanitary Protection

Continued sanitary protection of the well site from potential sources of contamination shall be provided either through ownership, zoning, easements, leasing or other means acceptable to the DOEC, fencing of the site may be required by the DOEC.

3.2.4.4.3. Wellhead Protection

A wellhead protection plan for continued protection of the wellhead from potential sources of contamination shall be provided, as determined by the DOEC.

3.2.4.5. Testing and Records

3.2.4.5.1. Yield and Drawdown Tests

Yield and drawdown tests shall:

1. Be performed on every production well after construction or subsequent treatment and prior to placement of the permanent pump;

2. Have the test methods clearly indicated in the project specifications;

3. Have a test pump capacity, at maximum anticipated drawdown, at least 1.5 times the quantity anticipated;

4. Provide for continuous pumping for at least 24 hours at the design pumping rate or until stabilized drawdown has continued for at least 6 hours when test pumped at 1.5 times the design pumping rate, and

5. Provide the following data:
   a) Test pump capacity-head characteristics;
   b) Static water level;
   c) Depth of test pump setting;
   d) Time of starting and ending each test cycle; and
   e) The zone of influence for the well or wells.

3.2.4.5.2. Plumbness and Alignment Requirements

1. Every well shall be tested for plumbness and alignment in accordance with AWWA standards.

2. The test method and allowable tolerance shall be clearly stated in the specifications.

3. If the well fails to meet these requirements, the engineer may accept it if it does not interfere with the installation or operation of the pump or uniform placement of grout.

3.2.4.5.3. Geological Data

Geological data shall:

1. Be determined from samples collected at 1.5 m intervals and at each pronounced change in formation;

2. Be recorded, and samples submitted to the DOEC; and

3. Be supplemented with information on accurate records of drillhole diameters and depths, assembled order of size and length of casing and liners, grouting depths, formations penetrated, water levels, and location of any blast charges.

3.2.4.6. General Well Construction

3.2.4.6.1. Drilling Fluids and Additives
Drilling fluids and additives shall:

1. Not impart any toxic substances to the water or promote bacterial contamination; and

2. Be acceptable to the DOEC.

3.2.4.6.2. Minimum Protected Depths
Minimum protected depths of drilled wells shall provide watertight construction to such depth as may be required by the DOEC, to

1. Exclude contamination; and

2. Seal off formations that are, or may be, contaminated or yield undesirable water.

3.2.4.6.3. Temporary Steel Casing
Temporary steel casing used for construction shall be capable of withstanding the structural load imposed during its installation and removal.

3.2.4.6.4. Permanent Steel Casing Pipe
Permanent steel casing pipe shall:
1. Be new single steel casing pipe meeting AWWA Standard A-100, ASTM or API specifications for water well construction;

2. Have minimum weights and thickness indicated in Table 3.5; Page 3-15

3. Have additional thickness and weight if minimum thickness is not considered sufficient to assure reasonable life of a well;

4. Be capable of withstanding forces to which it is subjected;

5. Be equipped with a drive shoe when driven; and

6. Have full circumferential welds or threaded coupling joints.

Table 3.5
Permanent Steel Casing Pipe Minimum Weight and Thickness

Steel Pipe					
Size (mm)	Diameter (mm)		Thickness (mm)	Weight per Foot (kg)	
	External	Internal		Plain Ends (calculated)	With Threads and Couplings (nominal)
150 id	168.275	154.051	7.112	8.605	8.700
200	219.075	202.717	8.179	12.950	13.313
250	255.905	254.508	9.271	18.361	18.983
300	323.850	304.800	9.525	22.480	23.201
350 od.	355.600	336.550	9.525	24.753	25.855
400	406.400	387.350	9.525	28.386	
450	457.200	438.150	9.525	32.019	
500	508.000	488.950	9.525	35.652	
550	558.800	533.400	12.700	52.077	
600	609.600	584.200	12.700	56.921	
650	660.400	635.000	12.700	61.766	
700	711.200	685.800	12.700	66.610	
750	762.000	736.600	12.700	71.454	
800	812.800	787.400	12.700	76.299	
850	863.600	838.200	12.700	81.143	
900	914.400	889.000	12.700	85.998	

3.2.4.6.5. Nonferrous Casing Materials

1. Approval of the use of any nonferrous material as well casing shall be subject to special determination by the DOEC prior to submission of plans and specifications.

2. Nonferrous material proposed as a well casing must be resistant to the corrosiveness of the water and to the stresses to which it will be subjected during installation, grouting and operation.

3.2.4.6.6. Packers

Packers shall be of a material that will not impart taste, odour, toxic substances or bacterial contamination to the well water. Lead packers shall not be used.

3.2.4.6.7. Screens

Screens shall:

1. Be constructed of materials resistant to damage by chemical action of groundwater or cleaning operations;

2. Have a size of openings based on sieve analysis of formation and/or gravel pack materials;

3. Have sufficient length and diameter to provide adequate specific capacity and low aperture entrance velocity. Usually the entrance velocity should not exceed 30 mm/s;

4. Be installed so that the pumping water level remains above the screen under all operation conditions;

5. Where applicable, be designed and installed to permit removal or replacement without adversely affecting water-tight construction of the well; and

6. Be provided with a bottom plate or washdown bottom fitting of the same material as the screen.

3.2.4.6.8. Grouting Requirements

All permanent well casing, except driven Schedule 40 steel casing with the approval of the DOEC, shall be surrounded by a minimum of 37 mm of grout to the depth required by the DOEC. All temporary construction casing shall be removed. Where removal is not possible or practical, the casing shall be withdrawn at least 1.5 m to insure grout contact with the native formation.

1. **Neat cement grout**
   a. Cement conforming to ASTM standard C150 and water, with not more than 23 liters of water per sack of cement, must be used for 37 mm openings.

   b. Additives may be used to increase fluidity subject to approval by the DOEC.

2. **Concrete grout**
   a. Equal parts of cement conforming to AWWA A100 Section 7, and sand, with not more 23 liters of water per sack of cement may be used for openings larger than 37 mm.

   b. Where an annular opening larger than 100 mm is available, gravel not larger than 12 mm in size may be added.

3. **Clay seal**
   a. Where an annular opening greater than 150 mm is available a clay seal of clean local clay mixed with at least 10 per cent swelling bentonite may be used when approved by the DOEC.

4. **Application**
   a. Sufficient annular opening shall be provided to permit a minimum of 37 mm of grout around permanent casings, including couplings.

   b. Prior to grouting through creviced or fractured formations, bentonite or similar materials may be added to the annular opening, in the manner indicated for grouting.

c. When the annular opening is less than 100 mm, grout shall be installed under pressure by means of a grout pump from the bottom of the annular opening upward in one continuous operation until the annular opening is filled.

d. When the annular opening is 100 mm or more and less than 30 m in depth, and concrete grout is used, it may be placed by gravity through a grout pipe installed to the bottom of the annular opening in one continuous operation until the annular is filled.

e. When the annular opening exceeds 150 mm, is less than 30 m in depth, and a clay seal is used, it may be placed by gravity.

f. After cement grouting is applied, work on the well shall be discontinued until the cement grout has properly set.

5. Guides

a. The casing must be provided with sufficient guides welded to the casing to permit unobstructed flow and uniform thickness of grout.

3.2.4.6.9. Upper Terminal Well Construction

1. Permanent casing for all groundwater sources shall project at least 0.3 m above the pumphouse floor or concrete apron surface and at least 0.45 m above final ground surface.

2. Where a well house is constructed, the floor surface shall be at least 150 mm above the final ground elevation.

3. Sites subject to flooding shall be provided with an earth mound to raise the pumphouse floor to an elevation at least 0.6 m above the highest known flood elevation, or other suitable protection as determined by the DOEC.

4. The top of the well casing at sites subject to flooding shall terminate at lest 0.9 m above the 100-year flood level or the highest known flood elevation, whichever is higher, or as the DOEC directs.

3.2.4.6.10. Development

1. Every well shall be developed to remove the native silts and clays, drilling mud or finer fraction of the gravel pack.

2. Development should continue until the maximum specific capacity is obtained from the completed well.

3. Where chemical conditioning is required, the specifications shall include provisions for the method, equipment, chemicals, testing for residual chemicals, and disposal of waste and inhibitors.

4. Where blasting procedures may be used, the specifications shall include the provisions for blasting and cleaning. Special attention shall be given to assure that blasting does not damage the grouting and casing.

3.2.4.6.11. Disinfection of New, Modified or Reconditioned Groundwater Sources

Disinfection of every new, modified or reconditioned groundwater source shall be provided:

1. After completion of work, if a substantial period elapses prior to test pumping or placement of permanent pumping equipment; and

2. After placement of permanent pumping equipment.

3.2.4.6.12. Capping Requirements

1. A welded metal plate or a threaded cap is the preferred method for capping a well.

2. At all times during the progress of work, the contractor shall provide protection to prevent tampering with the well or entrance of foreign materials.

3.2.4.6.13. Well Abandonment

1. Test wells and groundwater sources, which are not in use, shall be sealed by such methods as necessary to restore the controlling geological conditions, which existed prior to construction, or as directed by the DOEC in the *Guidelines for Sealing Groundwater Wells*.

2. Wells to be abandoned shall:
   a. Be sealed to prevent undesirable exchange of water from aquifer to another;

   b. Preferably be filled with neat cement grout;

   c. Have fill materials other than cement grout or concrete, disinfected and free of foreign materials; and

   d. When filled with cement grout or concrete, these materials shall be applied to the well hole through a pipe, tremie, or bailer.

3.2.4.7. Aquifer Types and Construction Methods – Special Conditions

3.2.4.7.1. Sand or Gravel Wells

1. If clay or hard pan is encountered above the water bearing formation, the permanent casing and grout shall extend through such materials.

2. If a sand or gravel aquifer is overlaid only by permeable soils the permanent casing and grout shall extend to at least 6 m below original and final ground elevation, whichever is lower.

3. If a temporary outer casing is used, it shall be completely withdrawn as grout is applied.

3.2.4.7.2. Gravel Pack Wells

1. Gravel pack shall be well rounded particles, 95% siliceous material, that are smooth and uniform, free of foreign material, properly sized, washed and then disinfected immediately prior to or during placement.

2. Gravel pack shall be placed in one uniform continuous operation.

3. Gravel refill pipes, when used, shall be Schedule 40 steel pipe incorporated within the pump foundation and terminated with screwed or welded caps at least 0.3 m above the pump house floor or concrete apron.

4. Gravel refill pipes located in the grouted annular opening shall be surrounded by a minimum of 37 mm of grout.

5. Protection from leakage of grout into the gravel pack or screen shall be provided.

6. Permanent inner and outer casings shall meet requirements of Section 3.2.4.6.4.

7. Minimum casing and grouted depth shall be acceptable to the DOEC.

3.2.4.7.3. Radial Water Collector

1. Locations of all caisson construction joints and porthole assemblies shall be indicated.

2. The caisson wall shall be reinforced to withstand the forces to which it will be subjected.

3. Radial collectors shall be in areas and at depths approved by the DOEC.

4. Provisions shall be made to assure that radial collectors are essentially horizontal.

5. The top of the caisson shall be covered with a watertight floor.

6. All openings in the floor shall be curbed and protected from entrance of foreign material.

7. The pump discharge piping shall not be placed through the caisson walls. In unique situations where this is not feasible, a watertight seal must be obtained at the wall.

3.2.4.7.4. Infiltration Lines

1. Infiltration lines may be considered only where geological conditions preclude the possibility of developing an acceptable drilled well.

2. The area around infiltration lines shall be under the control of the water purveyor for a distance acceptable to, or required by the DOEC.

3. Flow in the lines shall be by gravity to the collecting well.

3.2.4.7.5. Dug Wells

1. Dug wells may be considered as a source of public water supply where site-specific conditions permit.

2. A watertight cover shall be provided.

3. Minimum protective lining and grouted depth shall be at least 3 m below original, or final ground elevation, whichever is lower.

4. Openings shall be curbed and protected from entrance of foreign materials.

5. Pump discharge piping shall not be placed through the well casing or wall.

3.2.4.7.6. Limestone or Sandstone Wells

1. Where the depth of unconsolidated formations is more than 15 m, the permanent casing shall be firmly seated in uncreviced or unbroken rock. Grouting requirements shall be determined by the DOEC.

2. Where the depth of unconsolidated formations is less than 15 m, the depth of casing and grout shall be at least 15 m or as determined by the DOEC.

3.2.4.7.7. Naturally Flowing Wells

1. Flow shall be controlled.

2. Permanent casing and grout shall be provided.

3. If erosion of the confining bed appears likely, special protective construction may be required by the DOEC.

3.2.4.8. Well Pumps, Discharge Piping and Appurtenances

3.2.4.8.1. Line Shaft Pumps

Wells equipped with line shaft pumps shall:

1. Have the casing firmly connected to the pump structure or have the casing inserted into a recess extending at least 12 mm into the pump base;

2. Have the pump foundation and base designed to prevent water from coming into contact with the joint; and

3. Avoid the use of oil lubrication at pump settings less than 122 m.

3.2.4.8.2. Submersible Pumps

Where a submersible pump is used:

1. The top of the casing shall be effectively sealed against the entrance of water under all conditions of vibration or movement of conductors or cables; and

2. The electrical cable shall be firmly attached to the riser pipe at 6 m intervals or less.

3.2.4.8.3. Discharge Piping

The discharge piping shall:

1. Be designed so that the friction loss will be low;

2. Have control valves and appurtenances located above the pump house floor when an above-ground discharge is provided;

3. Be protected against the entrance of contamination;

4. Be equipped with a check valve, shutoff valve, a pressure gauge, a means of measuring flow, and a smooth nosed sampling tap located at a point where positive pressure is maintained;

5. Where applicable, be equipped with an air release-vacuum relief valve located upstream from the check valve, with exhaust/relief piping terminating in a down-turned position at least 0.71 m above the floor and covered with a 24-mesh corrosion resistant screen;

6. Be valved to permit test pumping and control of each well;

7. Have all exposed piping, valves and appurtenances protected against physical damage and freezing;

8. Be properly anchored to prevent movement; and

9. Be protected against surge or water hammer.

The discharge piping should be provided with a means of pumping to waste, but shall not be directly connected to a sewer.

3.2.4.8.4. Pitless Well Units

1. The DOEC must be contacted for approval of specific applications of pitless units.

2. Pitless units shall:

    a. Be shop-fabricated from the point of connection with the well casing to the unit cap or cover;

    b. Be threaded or welded to the well casing;

    c. Be of watertight construction throughout;

    d. Be of materials and weight at least equivalent and compatible to the casing;

    e. Have field connection to the lateral discharge from the pitless unit of threaded, flanged or mechanical joint connection; and

   f. Terminate at least 0.45 m above final ground elevation or 0.9 m above the 100-year flood level or the highest known flood elevation, whichever is higher, or as directed by the DOEC.

3. The design of the pitless unit shall make provisions for:

   a. Access to disinfect the well;

   b. A properly constructed casing vent meeting the requirements of Section 3.2.4.8.5;

   c. Facilities to measure water levels in the well, according to Section 3.2.4.8.6;

   d. A cover at the upper terminal of the well that will prevent the entrance of contamination;

   e. A contamination-proof entrance connection for electrical cable,

   f. An inside diameter as great as that of the well casing, up to and including casing diameters of 0.3 m, to facilitate work and repair on the well, pump, or well screen; and

   g. At least one check valve within the well casing or in compliance with requirements of the DOEC.

4. If the connection to the casing is by field weld, the shop-assembled unit must be designed specifically for field welding to the casing. The only field welding permitted will be that needed to connect a pitless unit to the casing.

3.2.4.8.5. Casing Vent

Provisions shall be made for venting the well casing to atmosphere. The vent shall terminate in a down turned position, at or above the top of the casing or pitless unit in a minimum 37 mm diameter opening covered with a 24 mesh, corrosion resistant screen. The pipe connecting the casing to the vent shall be of adequate size to provide rapid venting of the casing.

3.2.4.8.6. Water Level Measurement

1. Provision shall be made for periodic measurement of water levels in the completed well.

2. Where pneumatic water level measuring equipment is used it shall be made using corrosion resistant materials attached firmly to the top pipe or pump column and in such a manner as to prevent entrance of foreign materials.

3.2.4.8.7. Observation Wells

Observation wells shall be:

1. Constructed in accordance with the requirements for permanent wells if they are to remain in service after completion of a water supply well; and

2. Protected at the upper terminal to preclude entrance of foreign materials.

3.2.5. Langelier Index

The Langelier Index (LI) is an approximate measure of the degree of saturation of calcium carbonate in water. It is calculated using the pH, alkalinity, hardness, total dissolved solids, and water temperature. It is dependent on temperature and will vary with water temperature.

1. If the LI is negative – The water is under saturated with calcium carbonate and will tend to be corrosive in the distribution system.

2. If the LI is positive – The water is over saturated with calcium carbonate and will tend to deposit calcium carbonate forming scales in the distribution system.

3. If the LI is close to zero – The water is just saturated with calcium carbonate and will neither be strongly corrosive nor scale forming.

The LI is one of several tools used by the water operator for stabilizing water to control both corrosion and the deposition of scale. To ensure the long life of the distribution system it is best to have a LI close to one.

3.2.6. pH Adjustment

When first determining the amount of treatment required for a new water system or the upgrade of an existing water system, the pH of the raw water must be measured along with the approximate degree of saturation of calcium carbonate in the water using the Langelier Saturation Index. The Langelier Saturation Index will determine the potential corrosiveness of the water to be treated.

The pH of the raw water and the potential corrosiveness of the water are extremely important when the only form of treatment to be provided is disinfection using chlorine.

Most surface water in the province has very little alkalinity while some groundwater have excessive amounts of hardness. Based upon past experience, it has been shown that low alkalinity water, disinfected with gas chlorine, has a tendency to significantly lower the pH, which in turn causes excessive corrosiveness in the distribution system. In groundwater with a pH higher than 8, the disinfecting capability of chlorine, at this pH level, is compromised. The use of sodium hypochlorite in groundwater may raise the pH of the water even higher, which will affect disinfection. In such cases, the pH of water may have to be lowered.

3.2.7. Source Protection

Owners of water supply systems must apply to the DOEC as per Section 39 of the *Water Resources Act* for source and wellhead protection.

3.3. Water Treatment

The design of treatment processes and devices shall depend on the evaluation of the nature and quality of the particular water to be treated, seasonal variations, the desired quality of the finished water, and the mode of operation planned.

Water treatment facilities should be designed such that major process equipment and facilities are capable of supplying the maximum day demand for the 20 to 25 year projected design flows, plus an additional amount that will be sufficient to accommodate plant losses. Maximum Day demand is the maximum amount of water supplied to the system on any given day within a calendar year. Peak flows are the short-term flows expected to be experienced by a particular component of the system and will govern the sizing of many system components.

Minor process equipment such as piping, valves and chemical feed systems should be designed to accommodate future design flow, within the life expectancy of the components. Water treatment facilities should be designed to facilitate future expansion, if necessary. In each case, the designer may consider modularity and expandability as an option to the provision of surplus capacity.

3.3.1. Clarification

Plants designed for processing surface water shall:

1. Provide a minimum of two units each for rapid mix, flocculation and sedimentation;

2. Permit operation of the units either in series or parallel where softening is performed, and should permit series or parallel operation where plain clarification is performed;

3. Be constructed to permit units to be taken out of service without disrupting operation, and with drains or pumps sized to allow dewatering in a reasonable period of time;

4. Provide multiple-stage treatment facilities when required by the DOEC;

5. Be started manually following shutdown; and

6. Minimize hydraulic head losses between units to allow future changes in processes without the need for re-pumping.

3.3.1.1. Presedimentation

Waters containing high turbidity may require pre-treatment, usually sedimentation either with or without the addition of coagulation chemicals.

1. **Basin design** – presedimentation basins should have hopper bottoms or be equipped with continuous mechanical sludge removal apparatus, and provide arrangements for dewatering.

2. **Inlet** – incoming water shall be dispersed across the full width of the line of travel as quickly as possible: short-circuiting must be prevented.

3. **Bypass** – provisions for bypassing presedimentation basins shall be included.

4. **Detention time** – 3 hours detention is the minimum period recommended; greater detention may be required.

3.3.1.2. Rapid Mix

Rapid mix means the rapid dispersion of chemicals throughout the water to be treated, usually by violent agitation. The engineer shall submit the design basis for the velocity gradient (G value) selected, considering the chemicals to be added and water quality parameters.

1. **Equipment** – basins should be equipped with mechanical mixing devices. Static mixing maybe considered if treatment flow is not variable and can be justified by the design engineer.

2. **Mixing** – detention period should be not more than 30 seconds.

3. **Location** - the rapid mix and flocculation basin shall be as close together as possible.

3.3.1.3. Flocculation

Flocculation is the agitation of water at low velocities to promote the formation and growth of a settleable floc.

Inlet and outlet design should prevent short-circuiting and destruction of floc. Basin drains should be provided and should be a minimum of 200 mm diameter.

3.3.1.3.1. Detention

The flow-through velocity shall be no less than 0.15 m or greater than 0.45 m/min with a detention time of at least 30 min.

3.3.1.3.2. Equipment

Agitators shall be driven by variable speed drives with the peripheral paddle speed ranging from 0.15 to 0.6 m/s.

3.3.1.3.3. Piping

Flocculation and sedimentation basins should be as close together as possible. The velocity of flocculated water through pipes or conduits to settling basins shall be between 0.15 and 0.6 m/s. Allowances must be made to minimize turbulence at bends and changes in direction.

3.3.1.3.4. Alternate Design

Baffling may be used to provide for flocculation in small plants only after consultation with the DOEC. The design should be such that the velocities and flows noted above would be maintained.

3.3.1.3.5. Superstructure
A structure over the flocculation basins may be required.

3.3.1.4. Sedimentation

Sedimentation shall follow flocculation and the basins should provide quiescent settling for the removal of floc and other suspended solids. Basins may be either rectangular or circular and should have continuous mechanical sludge removal equipment. The detention time for effective clarification is dependent upon a number of factors related to basin design and the nature of the raw water. The following criteria apply to conventional sedimentation units.

3.3.1.4.1. Detention
The minimum detention time should be 4 hours. This may be reduced to 2 hours for lime-soda softening facilities treating only groundwater. Reduced sedimentation time may also be approved when equivalent effective settling is demonstrated, or when overflow rate is not more than 1.2 m/hr.

3.3.1.4.2. Inlet
Inlets shall be designed to distribute the water equally and at uniform velocities. Open ports, submerged ports, and similar entrance arrangements are required. A baffle should be constructed across the basin, close to the inlet end, and should project a sufficient distance below the water surface to dissipate inlet velocities and provide uniform flows across the basin.

3.3.1.4.3. Outlet
Outlet weirs or submerged orifices shall maintain velocities suitable for settling in the basin and to minimize short-circuiting. The use of submerged orifices is recommended in order to provide a volume above the orifices when there are fluctuations in flow. Outlet weirs and submerged orifices shall be designed as follows:

1. The rate of flow over the outlet weirs or through the submerged orifices shall not exceed 250 m^3/day/m of the outlet launder;

2. Submerged orifices should not be located lower than 0.9 m below the flow line; and

3. The entrance velocity through the submerged orifices shall not exceed 0.15 m/s.

3.3.1.4.4. Velocity
The velocity through settling basins should not exceed 0.15 m/s. The basins must be designed to minimize short-circuiting. Fixed and adjustable baffles must be provided, as necessary, to achieve the maximum potential for clarification.

3.3.1.4.5. Overflow
An overflow weir or pipe, which will establish the maximum water level desired on top of the filters, should be installed. The overflow shall discharge by gravity with a free fall at a location where the discharge will be noted.

3.3.1.4.6. Drainage

Basins must be provided with a means of dewatering. Basin bottoms should slope at approximately 8% toward the drain unless mechanical sludge removal equipment is installed. The discharge of drainage from any mixing or settling tank must be approved by the DOEC.

3.3.1.4.7. Superstructure

A superstructure over the sedimentation basins may be required. If there is no mechanical equipment in the basins, or if provisions are included for adequate monitoring under all expected weather conditions, a cover may be provided in lieu of a superstructure. The cover should be provided with manholes, equipped with raised curb and covers, as well as drop light connections, so that observations can be made, at several points, of the efficiency of sedimentation.

3.3.1.4.8. Sludge Collection

Mechanical sludge collection equipment should be provided.

3.3.1.4.9. Flushing Lines

Flushing lines or hydrants shall be provided, and must be equipped with backflow prevention devices acceptable to the DOEC.

3.3.1.4.10. Safety

Permanent ladders or handholds should be provided on the inside walls of the basin above the water level. Guardrails should be included. Compliance with other applicable safety requirements, such as the *Occupational Health and Safety Act* (OHSA), and regulations under the Act, shall be required.

3.3.1.4.11. Sludge Removal

Sludge removal design shall provide that:

1. Sludge pipes shall be not less than 75 mm in diameter and so arranged as to facilitate cleaning;

2. Entrance to sludge withdrawal piping shall prevent clogging;

3. Valves shall be located outside the tank for accessibility; and

4. The operator may observe and sample sludge being withdrawn from the unit.

3.3.1.4.12. Sludge Disposal

Facilities are required, by the DOEC, for the disposal of sludge (See Section 3.3.12.).

3.3.1.5. Solids Contact Unit

Units are generally acceptable for combined softening and clarification where water characteristics, especially temperature, do not fluctuate rapidly, flow rates are uniform, and operation is continuous. Before such units are considered as clarifiers without softening, specific approval of the DOEC shall be obtained. Clarifiers should be designed for the maximum uniform rate and should be adjustable to changes in flow, which are less than the design rate, and for changes in water characteristics. A minimum of two units, are required for surface water treatment.

3.3.1.5.1. Installation of Equipment
Supervision by a representative of the manufacturer shall be provided, with regard to all mechanical equipment, at the time of installation and initial operation.

3.3.1.5.2. Operating Equipment
The following shall be provided for plant operation:

1. A complete outfit of tools and accessories;

2. Necessary laboratory equipment; and

3. Adequate piping with suitable sampling taps located so as to permit the collection of water samples from critical portions of the units.

3.3.1.5.3. Chemical Feed
Chemicals shall be applied at such points and by such means as to insure satisfactory mixing of the chemicals with water.

3.3.1.5.4. Mixing
A rapid mix device or chamber ahead of solids contact units may be required by the DOEC to ensure proper mixing of the chemicals applied. Mixing devices shall be constructed to:

1. Provide good mixing of the raw water with previously formed sludge particles; and

2. Prevent deposition of solids in the mixing zone.

3.3.1.5.5. Flocculation
Flocculation equipment:

1. Shall be adjustable (speed and/or pitch);

2. Must provide for coagulation in separate chamber of baffled zone within the unit; and

3. Should provide the flocculation and mixing period to be not less than 30 minutes.

3.3.1.5.6. Sludge Concentrators

1. The equipment should provide either internal or external concentrators in order to obtain a concentrated sludge with a minimum of wastewater.

2. Large basins should have at least two sumps for collecting sludge located in the central flocculation zone.

3.3.1.5.7. Sludge Removal
Design of sludge removal process shall be as per Section 3.3.1.4.11.

3.3.1.5.8. Cross-connections

1. Blow-off outlets and drains must terminate and discharge at places satisfactory to the DOEC.

2. Cross-connection control must be included for potable water lines used to backflush sludge lines.

3.3.1.5.9. Detention Period

The detention time shall be established on the basis of the raw water characteristics and other local conditions that affect the operation of the unit. Based on design flow rates, the detention time should be:

1. 2 to 4 hours for suspended solids contact clarifiers and softeners treating surface water; and

2. 1 to 2 hours for the suspended solids contact softeners treating only groundwater.

The DOEC may alter detention time requirements.

3.3.1.5.10. Suspended Slurry Concentrate

Softening units should be designed so that continuous slurry concentrates of 1% or more, by weight, can be satisfactorily maintained.

3.3.1.5.11. Water Losses

1. Units shall be provided with suitable controls for sludge withdrawal.

2. Total water losses should not exceed 5% for clarifiers and 3% for softening units.

3. Solids concentration of sludge bled to waste should be 3% by weight for clarifiers and 5% by weight for softeners.

3.3.1.5.12. Weirs or Orifices

The units should be equipped with either overflow weirs or orifices constructed so that water at the surface of the unit does not travel over 3 m horizontally to the collection trough.

1. Weirs shall be adjustable, and at least equivalent in length to the perimeter of the tank.

   a) Weir loading shall not exceed 120 L/min/m of weir length for units used for clarifiers, and 240 L/min/m of weir length for units used for softeners.

2. Where orifices are used, the loading rates per foot of launder rates should be equivalent to weir loadings. Either shall produce uniform rising rates over the entire area of the tank.

3.3.1.5.13. Upflow Rates

Unless supporting data is submitted to the DOEC to justify rates exceeding the following, rates shall not exceed:

1. 2.4 m/hr at the sludge separation line for units used for clarifiers; and

2. 4.2 m/hr at the slurry separation line, for units used for softeners.

3.3.1.6. Tube or Plate Settlers

Proposals for tube settler unit clarification must include pilot plant and/or full-scale demonstration data on water with similar quality prior to the preparation of final plans and specifications satisfactory to the DOEC. Settler units consisting of various shaped tubes or plates, which are installed, in multiple layers and at an angle to the flow may be used for sedimentation, following flocculation. The proposal would form part of the Technical Report (see Section 2.1).

1. **Inlet and Outlet Considerations** – Design to maintain velocities suitable for settling in the basin and to minimize short-circuiting. Plate units shall be designed to minimize misdistribution across the units.

2. **Drainage** – Drain piping from the settler units must be sized to facilitate a quick flush of the settler units and to prevent flooding of other portions of the plant.

3. **Protection from Freezing** – Although most units will be located within a plant, outdoor installations must provide sufficient freeboard above the top of the settlers to prevent freezing in the units. A cover or enclosure is strongly recommended.

4. **Application Rate for Tubes** – A maximum rate of 4.8 m/hr for tube settlers, unless higher rates are successfully shown through pilot plant or in-plant demonstration studies.

5. **Application Rates for Plates** – A maximum plate loading rate of 1.2 m/hr based on 80% of the projected horizontal plate area.

6. **Flushing Lines** – Flushing lines shall be provided to facilitate maintenance and must be properly protected against backflow or back-siphonage.

3.3.2. Filtration

Acceptable filters include:
1. Rapid rate gravity filters;
2. Rapid rate pressure filters;
3. Diatomaceous earth filtration;
4. Slow sand filtration;
5. Direct filtration;
6. Deep bed rapid rate gravity filters;
7. Biologically active filters;
8. Membrane filtration;
9. Reverse Osmosis; and
10. Bag and cartridge filters.

The application of any one type must be supported by water quality data representing a reasonable period of time to characterize variations in water quality. Experimental treatment studies may be required to demonstrate the applicability of the method of filtration proposed.

3.3.2.1. Rapid Rate Gravity Filters

3.3.2.1.1. Pretreatment

The use of rapid rate gravity filters shall require pretreatment.

3.3.2.1.2. Rate of Filtration

The rate of filtration should be determined through consideration of such factors as raw water quality, degree of pretreatment provided, filter media, water quality control parameters, competency of operating personnel, and other factors as required by the DOEC. In any case, the filter rate must be proposed and justified by the design engineer to the satisfaction of the DOEC prior to the preparation of the final plans and specifications.

3.3.2.1.3. Number of Units

At a minimum, 2 units shall be provided. Each shall be capable of meeting the plant design capacity (normally the projected maximum daily demand) at the approved filtration rate. Where more than 2 filter units are provided, the filters shall be capable of meeting the plant design capacity at the approved filtration rate with one filter removed from service. Where declining rate filtration is provided, the variable aspect of filtration rates, and the number of filters must be considered when determining the design capacity for the filters.

3.3.2.1.4. Structural Details and Hydraulics

The filter structure should be designed to provide for:

1. Vertical walls within the filter;
2. No protrusion of the filter walls into the filter media;
3. Cover by a superstructure;
4. Head room to permit inspection and operation;
5. Minimum filter box depth of 2.6 m;
6. Minimum water depth over the surface of the filter media of 0.9 m;
7. Filter effluent pipes in the clear well which should be trapped to prevent air from entering the bottom of the filters;
8. Prevention of floor drainage to the filter with a minimum 100 mm curb around the filters;
9. An overflow to prevent water from rising above the walls of the filters;
10. Water levels in the filters to be below the filter operating floor to prevent sweating of the filter walls;
11. A maximum velocity of 0.6 m/s in influent pipes or conduits;

12. The influent pipes and conduits shall be straight with crosses or clean-out chambers at changes in direction or following lime-soda softening to permit cleaning;

13. Washwater drain capacity to carry maximum flow;

14. Walkways around filters, to be not less than 600 mm wide;

15. Safety handrails or walls around all filter walkways; and

16. Construction to prevent cross-connections and common walls between potable and non-potable water.

3.3.2.1.5. Washwater Troughs

Washwater troughs should be constructed to have:

1. The bottom elevation above the maximum level of expanded media during back-washing;

2. A 50 mm freeboard at the maximum rate of wash;

3. The top edge level and all at the same elevation;

4. Spacing so that each trough serves the same number of square meters of filter area; and

5. Maximum horizontal travel of suspended particles to reach the trough not to exceed 0.9 m.

3.3.2.1.6. Filter Material

The media shall be clean silica sand or other natural or synthetic media, approved by the DOEC, having the following characteristics:

1. Total depth of not less than 0.6 m and generally not more than 0.76 m;

2. Effective size range of the smallest material no greater than 0.45 mm to 0.55 mm;

3. Uniformity coefficient of the smallest material not greater than 1.65,

4. A minimum of 0.3 m of media with an effective size range no greater than 0.45 mm to 0.55 mm and a specific gravity greater than other filtering materials within the filter,

5. Types of Filter Media:

    a. ***Anthracite*** - Clean crushed anthracite, or a combination of anthracite and other media may be considered on the basis of experimental data specific to the project and shall have:

        i) Effective size of 0.45 mm – 0.55 mm with uniformity coefficient not greater than 1.65 when used alone;

ii) Effective size of 0.8 mm – 1.2 mm with a uniformity coefficient not greater than 1.85 when used as a cap; and

iii) Effective size for anthracite used as a single media on potable groundwater for iron and manganese removal only shall be a maximum of 0.8 mm (effective sizes greater than 0.8 mm may be approved based upon onsite pilot plant studies or other demonstration acceptable to the DOEC).

If the anthracite grains are too small, excessive losses will be incurred during the minimum backwash that is required to clean the sand effectively.

b. ***Sand*** – Shall have effective size of 0.45 mm to 0.55 mm, and uniformity coefficient of not greater than 1.65.

c. ***Granular activated carbon (GAC)*** – Granular activated carbon as a single media may be considered for filtration only after pilot or full scale testing and with prior approval of the DOEC. The design shall include the following:

i) The media must meet the basic specifications for filter media as given in Section 3.3.2.1.6 (1) through (4) except that larger size media may be allowed by the DOEC where full scale tests have demonstrated that treatment goals can be met under all conditions;

ii) There must be provisions for a free chlorine residual and adequate contact time in the water following the filters and prior to distribution (see Sections 4.2.1 and 4.2.3);

iii) There must be means for periodic treatment of filter material for control of bacteria and other growth; and

iv) Provisions must be made for frequent replacement or regeneration.

d. ***Torpedo Sand*** – A 75 mm layer of torpedo sand should be used as a supporting media for filter sand where supporting gravel is used, and shall have effective size of 0.8 mm to 2.0 mm, and uniformity coefficient not greater than 1.7.

e. ***Gravel*** - Gravel, when used as the supporting media, shall consist of cleaned and washed, hard, durable, rounded silica particles and shall not include flat or elongated particles. The coarsest gravel shall be 64 mm in size when the gravel rests directly on a lateral system, and must extend above the top of the perforated laterals. Not less than four layers of gravel shall be provided in accordance with the size and depth distribution, outlined in Table 3.6, when used with perforated laterals.

f. ***Other Media*** – Other media will be considered based on experimental data and operating experience.

Table 3.6
Size and Depth Distribution

Size (mm)	Depth (mm)
64 – 38	125 – 205
38 – 19	76 – 125
19 – 12.5	76 – 125
12.5 – 5	50 – 76
5 – 2.5	50 – 76

Reduction of gravel depth and other size gradations may be considered upon justification to the DOEC for slow sand filtration or when proprietary filter bottoms are specified.

3.3.2.1.7. Filter Bottoms and Strainer Systems

Porous plate bottoms shall not be used where iron or manganese may clog them or with water softened with lime. The design of manifold-type collection systems shall:

1. Minimize loss of pressure in the manifold and laterals;

2. Ensure even distribution of washwater and even rate of filtration over the entire area;

3. Provide the ratio of the area of the final openings of the strainer systems to the area of the area of the filter at about 0.003;

4. Provide the total cross-sectional area of the laterals at about twice the total area of the final openings;

5. Provide the cross-sectional area of the manifold at 1.5 to 2 times the total area of the final openings; and

6. Direct lateral perforations without strainers downward.

3.3.2.1.8. Surface Wash or Subsurface Wash

Surface or subsurface wash facilities are required except for filters used exclusively for iron or manganese removal, and may be accomplished by a system of fixed nozzles or a revolving type apparatus. All devices shall be designed with:

1. Provisions for water pressures of at least 310 kPa,

2. A properly installed vacuum breaker or other approved device to prevent back-siphonage if connected to the treated water system;

3. A rate of flow of 1.36 L/m^2s of filter areas (4.9 m/hr) with fixed nozzles or 0.34 L/m^2s (1.2 m/hr) with revolving arms, and

4. Air wash based on experimental data and operating experiences.

3.3.2.1.9. Air Scouring

Air scouring can be considered in place of surface wash, and shall be designed as follows:

1. Air flow for air scouring the filter must be 0.9 – 1.5 $m^3/min/m^2$ when the air is introduced in the underdrain; a lower air rate must be used when the air scour distribution system is placed above the underdrains;

2. A method for avoiding excessive loss of the filter media during backwashing must be provided;

3. Air scouring must be followed by a fluidization wash sufficient to re-stratify the media;

4. Air must be free from contamination;

5. Air scour distribution systems should be placed below the media and supporting bed interface; if placed at the interface the air scour nozzles shall be designed to prevent media from clogging the nozzles or entering the air distribution system;

6. Piping for the air distribution system shall not be flexible hose which will collapse when not under air pressure, and shall not be a relatively soft material which may erode at the orifice opening with the passage of air at high velocity;

7. Air delivery piping shall not pass down through the filter media, nor shall there be any arrangement in the filter design which would allow short circuiting between the applied unfiltered water and the filtered water;

8. Consideration should be given to maintenance and replacement of air delivery piping;

9. The backwash water delivery system must be capable of 37 $m/hr/m^2$ of surface area; however, when air scour is provided, the backwash water rate must be variable and should not exceed 20 $m/hr/m^2$ of surface area unless operating experience shows that a higher rate is necessary to remove scoured particles from filter media surfaces;

10. The filter underdrains shall be designed to accommodate air scour piping when the piping is installed in the underdrain, and

11. The provisions of Section 3.3.2.1.11 shall be followed.

3.3.2.1.10. Appurtenances

1. The following shall be provided for every filter:

   a. Influent and effluent sampling taps,

   b. An indicating loss of head gauge,

   c. An indicating rate-of-flow meter. A modified rate controller, which limits the rate of filtration to a maximum rate, may be used. However, equipment that simply maintains a constant water level on the filters is not acceptable, unless the rate of flow unto the filter is properly controlled. A pump or a flow meter in each filter effluent line may be used as the limiting device for the rate of filtration only after consultation with the DOEC, and

d. Where used for surface water, provisions for filtering to waste with appropriate measures for backflow prevention.

2. The following should be provided for all filters:

   a. A continuous or rotating cycle turbidity recording device for surface water treatment plants,

   b. Wall sleeves providing access to the filter interior at several locations for sampling or pressure sensing,

   c. A 25 to 38 mm diameter pressure hose and storage rack at the operating floor for washing filter walls,

   d. Provisions for draining the filter to waste with appropriate measures for backflow prevention, and
   e. Particle monitoring equipment as a means to enhance overall treatment options where used for surface water.

3.3.2.1.11. Backwash

Provisions should be made for washing filters as follows:

1. A minimum rate of 37 m/hr, consistent with water temperatures and specific gravity of the filter media. A rate of 50 m/hr or a rate necessary to provide for a 50% expansion of the filter bed is recommended. A reduced rate of 24 m/hr may be acceptable for full depth anthracite or granular activated carbon filters. Backwashing rates may be reduced to 12 to 18 m/hr for systems using air scour;

2. Filtered water provided at the required rate by washwater tanks, a washwater pump, from the high service main, or a combination of these;

3. Washwater pumps in duplicate unless an alternate means of obtaining washwater is available;

4. Not less than 15 minute wash of one filter at the design rate of wash;

5. A washwater regulator or valve on the main washwater line to obtain the desired rate of filter wash with the washwater valves on the individual filters open wide;

6. A rate-of-flow indicator, preferably with a totalizer, on the main washwater line, located so that it can be easily read by the operator during the washing process;

7. Capability to backwash all filters within a 24-hour period;

8. Design to prevent rapid changes in backwash water flow, and

9. Backwash shall be operator initiated; automated systems shall be operator adjustable.

3.3.2.1.12. Miscellaneous

Roof drains shall not discharge into the filters or basins and conduits preceding the filters.

3.3.2.2. Rapid Rate Pressure Filters

The normal use of these filters is for iron and manganese removal. Pressure filters shall not be used in the filtration of polluted waters or following lime-soda softening. Minimum criteria relative to number, rate of filtration, structural details and hydraulics, filter media, etc., provided for rapid rate gravity filters also apply to pressure filters where appropriate.

3.3.2.2.1. Rate of Filtration

The rate should not exceed 7.2 m/hr except where in-plant testing, as approved by the DOEC, has demonstrated satisfactory results at higher rates.

3.3.2.2.2. Details of Design

The filters shall be designed to provide for:

1. Loss of pressure gauges on the inlet and outlet pipes of each filter;

2. An easily readable meter or flow indicator on each battery of filters. A flow indicator is recommended for each filtering unit;

3. Filtration and backwashing of each filter individually with an arrangement of piping as simple as possible to accomplish these purposes;

4. Minimum sidewall shell height of 1.5 m. A corresponding reduction in sidewall height is acceptable where proprietary bottoms permit reduction of the gravel depth;

5. The top of the washwater collectors to be at least 450 mm above the surface of the media;

6. The underdrain system to efficiently collect the filtered water and to uniformly distribute the backwash water at a rate not less than 37 m/hr;

7. Backwash flow indicators and controls that are easily readable while operating the control valves;

8. An air release valve on the highest points of each filter;

9. An accessible manhole to facilitate inspections and repairs for filters 0.9 m or more in diameter. Sufficient handholds shall be provided for filters less than 0.9 m in diameter. Manholes should be at least 0.6 m in diameter where feasible;

10. Means to observe the wastewater during backwashing, and

11. Construction to prevent cross-connection.

3.3.2.3. Diatomaceous Earth Filtration

The use of these filters may be considered for application to surface water with low turbidity and low bacterial contamination, and may be used for iron removal for groundwater providing the removal is effective and the water is of satisfactory sanitary quality before treatment.

3.3.2.3.1. Conditions of Use

Diatomaceous earth filters are expressly excluded from consideration for the following conditions:

1. Bacteria removal,

2. Colour removal,

3. Turbidity removal, where either the gross quantity of turbidity is high or the turbidity exhibits poor filterability characteristics, and

4. Filtration of water with high algae counts.

3.3.2.3.2. Pilot Plant Study

Installation of a diatomaceous earth filtration system shall be preceded by a pilot plant study on the water to be treated.

1. Conditions of the study such as duration, filter rates, head loss accumulation, slurry feed rates, turbidity removal, bacteria removal, etc., must be approved by the DOEC prior to the study.

2. Satisfactory pilot plant results must be obtained prior to preparation of final construction plans and specifications.

3. The pilot plant study must demonstrate the ability of the system to meet the latest version of the *GCDWQ* at all times.

3.3.2.3.3. Types of Filters

Pressure or vacuum diatomaceous earth filtration units will be considered for approval. However, the vacuum type is preferred for its ability to accommodate a design which permits observation of the filter surfaces to determine proper cleaning, damage to a filter element, and adequate coating over the entire filter area.

3.3.2.3.4. Treated Water Storage

Treated water storage capacity in excess of normal requirements shall be provided to:

1. Allow operation of the filters at a uniform rate during all conditions of system demand at or below the approved filtration rate, and

2. Guarantee continuity of the service during adverse raw water conditions without by-passing the system.

3.3.2.3.5. Number of Units

See Section 3.3.2.1.3.

3.3.2.3.6. Pre-coat

1. **Application** - A uniform pre-coat shall be applied hydraulically to each septum by introducing a slurry to the tank influent line and employing a filter-to-waste or recirculation system.

2. **Quantity** - Diatomaceous earth in the amount of 0.5 kg/m^2, or an amount sufficient to apply 1.6 mm coating, should be used with recirculation. When pre-coating is accomplished with a filter-to-waste system, 0.7 - 1.0 kg/m^2 is recommended.

3.3.2.3.7. Body Feed

A body feed system to apply additional amounts of diatomaceous earth slurry during the filter run is required to avoid short filter runs or excessive head losses.

1. Quantity - Rate of body feed is dependent on raw water quality and characteristics, and must be determined in the pilot plant study.

2. Operation and maintenance can be simplified by providing accessibility to the feed system and slurry lines.

3. Continuous mixing of the body feed slurry is required.

3.3.2.3.8. Filtration

1. **Rate of Filtration** - The recommended normal rate is 2.4 m/hr with a recommended maximum of 3.7 m/hr. The filtration rate shall be controlled by a positive means.

2. **Head Loss** – The head loss shall not exceed 210 kPa for pressure diatomaceous earth filters, or a vacuum of –51 kPa for a vacuum system.

3. **Recirculation** – A recirculation or holding pump shall be employed to maintain differential pressure across the filter when the unit is not in operation in order to prevent the filter cake from dropping off the filter elements. A minimum recirculation of 0.24 m/hr shall be provided.

4. **Septum or Filter Element** – The filter elements shall be structurally capable of withstanding maximum pressure and velocity variations during filtration and backwash cycles, and shall be spaced such that no less than 25 mm is provided between elements or between any element and a wall.

5. **Inlet Design** – The filter influent shall be designed to prevent scour of the diatomaceous earth from the filter element.

3.3.2.3.9. Backwash

A satisfactory method to thoroughly remove and dispose of spent filter cake shall be provided.

3.3.2.3.10. Appurtenances

The following shall be provided for every filter:

1. Sampling taps for raw water and filtered water;

2. Loss of head or differential pressure gauge;

3. Rate-of-flow indicator, preferably with totalizer;

4. A throttling valve used to reduce rates below normal during adverse raw water conditions;

5. Evaluation of the need for body feed, recirculation, and any other pumps, in accordance with Section 3.5.3; and

6. Provisions for filtering to waste with appropriate measures for backflow prevention (see Section 3.3.12).

3.3.2.3.11. Monitoring

1. A continuous monitoring turbidimeter with recorder is required on the filter effluent for plants treating surface water.

2. Particle monitoring equipment should be provided as a means to enhance overall treatment operations for plants treating surface water.

3.3.2.4. Slow Sand Filters

The use of these filters shall require prior engineering studies to demonstrate the adequacy and suitability of this method of filtration for the specific raw water supply.

3.3.2.4.1. Quality of Raw Water

Slow rate gravity filtration shall be limited to waters having maximum turbidity of 10 units and maximum colour of 15 units; such turbidity must not be attributable to colloidal clay. Raw water quality data must include examinations for algae.

3.3.2.4.2. Number of Units

At least two units shall be provided. Where only two units are provided, each shall be capable of meeting the plant design capacity (normally the projected maximum daily demand) at the approved filtration rate. Where more than two filter units are provided, the filters shall be capable of meeting the plant design capacity at the approved filtration rate with one filter removed from service.

3.3.2.4.3. Structural Details and Hydraulics

Slow rate gravity filters shall be designed to provide:

1. A cover;

2. Headroom to permit normal movement by operating personnel for scraping and sand removal operations;
3. Adequate access hatches and access ports for handling of sand and for ventilation;
4. Filtration to waste;
5. An overflow at the maximum filter water level; and
6. Protection from freezing.

3.3.2.4.4. Rates of Filtration

The permissible rates of filtration shall be determined by the quality of the raw water and shall be on the basis of experimental data derived from the water to be treated. The normal rate may be 0.04 to 0.40 m/hr, with somewhat higher rates acceptable when demonstrated to the satisfaction of the DOEC.

3.3.2.4.5. Underdrains

Each filter unit shall be equipped with a main drain and an adequate number of lateral underdrains to collect the filtered water. The underdrains shall be so spaced that the maximum velocity of the water flow in the underdrain will not exceed 0.325 m/s. The maximum spacing of laterals shall not exceed 0.9 m if pipe laterals are used.

3.3.2.4.6. Filtering Material

1. Filter sand shall be placed on graded gravel layers for a minimum depth of 0.75 m.
2. The effective size shall be between 0.15 mm and 0.30 mm. Larger sizes may be considered by the DOEC; a pilot study may be required
3. The uniformity coefficient shall not exceed 2.5.
4. The sand shall be cleaned and washed free from foreign matter.
5. The sand shall be re-bedded when scraping has reduced the bed depth to no less than 0.475 m. Where sand is to be reused in order to provide biological seeding and shortening of the ripening process, re-bedding shall utilize a “throw over” technique whereby new sand is placed on the support gravel and existing sand is replaced on top of the new sand.

3.3.2.4.7. Filter Gravel

The supporting gravel should be similar to the size and depth distribution provided for rapid rate gravity filters (See Section 3.3.2.1.6. (5.e & f)).

3.3.2.4.8. Depth of Water on Filter Beds

Design shall provide a depth of at least 0.9 to 1.8 m of water over the sand. Influent water shall not scour the sand surface.

3.3.2.4.9. Control Appurtenances

Each filter shall be equipped with:

1. Loss of head gauge;
2. An orifice, Venturi meter, or other suitable means of discharge measurement installed on each filter to control the rate of filtration; and

3. An effluent pipe designed to maintain the water level above the top of the filter sand.

3.3.2.4.10. Ripening

Slow sand filters shall be operated to waste after scraping or re-bedding during a ripening period until the filter effluent turbidity falls to consistently below 1 NTU.

3.3.2.5. Direct Filtration

Direct filtration, as used herein, refers to the filtration of surface water following chemical coagulation and possibly flocculation but without prior settling. The nature of the treatment process will depend upon the raw water quality. A full-scale direct filtration plant shall not be constructed without prior pilot studies, which are acceptable to the DOEC. In-plant demonstration studies may be appropriate where conventional treatment plants are converted to direct filtration. Where direct filtration is proposed, an engineering report shall be submitted prior to conducting pilot plant or in-plant demonstration studies.

3.3.2.5.1. Technical Report

In addition to the items considered in Section 2.1, the Technical Report should include a historical summary of meteorological conditions and of raw water quality with special reference to fluctuations in quality, and possible sources of contamination. The following raw water parameters should be evaluated in the report:

1. Colour;
2. Turbidity;
3. Bacterial concentration;
4. Microscopic biological organisms;
5. Temperature;
6. Total solids;
7. General inorganic chemical characteristics; and
8. Additional parameters as required by the DOEC.

The report should also include a description of methods and work to be done during the pilot plant studies or, where appropriate, an in-plant demonstration studies.

3.3.2.5.2. Pilot Plant Studies

After approval of the Technical Report, pilot studies or in-plant demonstration studies shall be conducted. The studies must be conducted over a sufficient time to treat all expected raw water conditions throughout the year. The studies shall emphasize, but not be limited to, the following items:

1. Chemical mixing conditions including shear gradients and detention periods;
2. Chemical feed rates;

3. Use of various coagulants and coagulant aids;
4. Flocculation conditions;
5. Filtration rates;
6. Filter gradation, types of media and depth of media;
7. Filter breakthrough conditions; and
8. Adverse impact of recycling backwash water due to solids, algae, trihalomethane formation, and similar problems.

Prior to the installation of design plans and specifications, a final report including the engineer's design recommendations shall be submitted to the DOEC.

The pilot plant filter must be of a similar type and operated in the same manner as proposed for full-scale operation.

The pilot studies must demonstrate the minimum contact time necessary for optimum filtration for each coagulant proposed.

3.3.2.5.3. Pretreatment – Rapid Mix and Flocculation

The final rapid mix and flocculation basin design should be based on the pilot plant or in-plant demonstration studies augmented with applicable portions of Section 3.3.1.2 and Section 3.3.1.3.

3.3.2.5.4. Filtration

1. Filters shall be rapid rate gravity filters with dual or mixed media. The final filter design shall be based on the pilot plant or in-plant demonstration studies and all portions of Section 3.3.2.1. Pressure filters or single media sand filters shall not be used.

2. A continuous recording turbidimeter shall be installed on each filter effluent line and on the composite filter effluent line.

3. Additional continuous monitoring equipment to assist in control of coagulant dose may be required by the DOEC.

3.3.2.5.5. Siting Requirements

The plant design and land ownership surrounding the plant shall allow for the installation of conventional sedimentation basins should it be found that such are necessary.

3.3.2.6. Deep Bed Rapid Rate Gravity Filters

1. Deep bed rapid rate gravity filters, as used herein, generally refers to rapid rate gravity filters with filter material depths greater than 1.2 m. Filter media sizes are typically larger than those listed in Section 3.3.2.1.6. (5).

2. Deep bed rapid rate filters may be considered based on pilot studies pre-approved by the DOEC.

3. The final filter design shall be based on the pilot plant studies and shall comply with all applicable portions of Section 3.3.2.1. Careful attention shall be paid to the design of the backwash system which usually includes simultaneous air scour and water backwash at subfluidization velocities.

3.3.2.7. Biologically Active Filters

1. Biologically active filtration, as used herein, refers to the filtration of surface water (or ground water with iron, manganese or significant natural organic material), which includes the establishment and maintenance of biological activity within the filtration media.

2. Objectives of biologically active filtration may include control of disinfection by-products (DBPs), increased disinfection stability, reduction of substrates for microbial re-growth, breakdown of small quantities of synthetic organic chemicals, reduction of ammonia-nitrogen, and oxidation of iron and manganese. Biological activity can have an adverse impact on turbidity, particle or microbial pathogen removal, disinfection practices, head loss development, filter run times and distribution system corrosion. Design and operation should ensure that aerobic conditions are maintained at all times. Biologically active filtration often includes the use of ozone as a pre-oxidant/disinfectant, which breaks down natural organic materials into biodegradable organic matter, and granular activated carbon filter media, which may promote denser biofilms.

3. Biologically active filters may be considered based on pilot studies pre-approved by the DOEC. The study objectives must be clearly defined and must ensure the microbial quality of the filtered water under all anticipated conditions of operation. The pilot study shall be of sufficient duration to ensure establishment of full biological activity; often greater than three months is required.

4. The final filter design shall be based on the pilot plant studies and shall comply with all acceptable portions of Section 3.3.2.1.

3.3.2.8. Membrane Filtration for Treating Surface Sources

Low pressure membrane filtration technology has emerged as a viable option for addressing current and future drinking water regulations related to treatment of surface water sources. Recent research and applied full-scale facilities have demonstrated the efficient performance of both Micro filtration (MF) and Ultra filtration (UF) as feasible treatment alternatives to traditional granular media processes. Both MF and UF have been shown to be effective in removing identified parameters, such as, giardia/cryptosporidium, bacteria, turbidity and possibly viruses. The following provides a brief description of the characteristics of each process as well as selection and design considerations.

3.3.2.8.1. Characteristics

1. MF and UF membranes are most commonly made from organic polymers (for example, cellulose acetate, polysulfones, polyamides, polypropylene or polycarbonate). The physical configurations include hollow-fibre, spiral wound and tubular. MF membranes are capable

of removing particles with sizes down to 0.1 to 0.2 microns. UF processes have a probable lower cut-off rating of 0.005 to 0.1 microns.

2. Typical flux (rate of finished water permeate per unit membrane surface area) at 20EC for MF ranges between 20 to 41 m^3/m^2/day whereas the typical UF flux range is 4.0 to 20 m^3/m^2/day. Required operating pressures range from 35 to 70 kPa for MF and 100 to 500 kPa for UF.
3. Since both processes have relatively small membrane pore diameters, membrane fouling, caused by organic and inorganic as well as physical contaminants, is expected. Periodic flushing and cleaning is employed once a targeted transmembrane pressure differential has been reached. Typical cleaning agents utilized include acids, bases, surfactants, enzymes and certain oxidants, depending upon membrane material and foulants encountered.

4. Overall treatment requirements must be discussed with, and approved by, the DOEC. Disinfection is required with membrane filtration.

3.3.2.8.2. Selection and Design Considerations

1. A review of historical source raw water quality data, including turbidity and/or particle counts, organic loading, temperature differentials as well as other inorganic and physical parameters, can indicate whether either process is feasible. The degree of pretreatment, if any, may also be ascertained. Design consideration and membrane selection at this phase must also address the issue of target removal efficiencies versus acceptable transmembrane pressure differentials.

2. The useful life expectancy of a particular membrane under consideration should be evaluated. A membrane replacement frequency is a significant factor in operation and maintenance cost comparisons in the selection of the process.

3. Many membrane materials are incompatible with certain oxidants. If the system must rely on pre-treatment oxidants for other purposes, for example, zebra mussel control, taste and odour control, the selection of the membrane material becomes a significant design consideration.

4. The source water temperature can significantly impact the flux of the membrane under consideration. At low water temperatures the flux can be reduced appreciably, possibly impacting process feasibility or the number of membrane units required for a full-scale facility.

5. Flushing volumes can range from 5 to 25% of the permeate flow, depending upon the frequency of flushing/cleaning and the degree of fouling, and is an important factor in specifying the number of treatment units required.

6. An appropriate level of finished water monitoring should be provided to routinely evaluate membrane and housing integrity and overall filtration performance. Monitoring options may include particle counters, manual and/or automated pressure testing or air diffusion testing.

7. Cross connection considerations are necessary, particularly with regard to chemical feeds

used for membrane cleaning.

8. Redundancy of critical control components must be considered in the final design.

9. Other post-membrane treatment requirements must be evaluated in the final design to address other contaminants of concern such as colour and disinfection by-product precursors.

10. Prior to initiating the design of a membrane treatment facility, the DOEC should be contacted to determine if a pilot plant study would be required. In most cases, a pilot plant study will be necessary to determine the best membrane to use, particulate/organism removal efficiencies, cold and warm water flux, the need for pre-treatment, fouling potential, operating and transmembrane pressure and other design considerations. The DOEC should be contacted prior to conducting the pilot study to establish the protocol to be followed.

3.3.2.9. Reverse Osmosis

Reverse osmosis is a physical process in which suitably pretreated water is delivered at high pressure against a semi-permeable membrane. The membrane rejects most solute ions and molecules, while allowing water of very low mineral content to pass through. The process produces a reject concentrate waste stream in addition to the clear permeate product. Reverse osmosis systems have been successfully applied to saline groundwaters, brackish waters, and seawater.

The following items should be considered in evaluating the applicability for reverse osmosis:

1. **Membrane Selection -** Two types of membranes are typically used. These are Cellulose Acetate and Polyamide/Composite. Membrane configurations include tubular, spiral wound and hollow fine fibre. Operational conditions and useful life vary depending on the type of membrane selected.

2. **Useful Life of the Membrane** - The membrane represents a major cost component in the overall water system. Membrane replacement frequency can significantly affect the overall cost of operating the treatment facility.

3. **Pretreatment Requirements** - Acceptable feedwater characteristics are dependent on the type of membrane and operational parameters of the system. Without pretreatment, the membrane may become severely fouled and shorten its useful life. Pretreatment may be needed for turbidity reduction, iron or manganese removal, stabilization of the water to prevent scale formation, microbial control, chlorine removal, dissolved solids reduction, pH adjustment or hardness reduction.

4. **Treatment Efficiency** - Reverse osmosis is highly efficient in removing metallic salts and ions from the raw water. Efficiencies, however, do vary depending on the ion being removed and the membrane utilized. For most commonly encountered ions, removal efficiencies will range from 85% to over 99%. Organics removal is dependent on the molecular weight, the shape of the organic molecule and the pore size of the membrane utilized. Removal efficiencies may range from as high as 99% to less than 30%.

5. **Bypass Water** - Reverse osmosis permeate will be virtually demineralised. The design should provide for a portion of the raw water to bypass the unit to maintain stable water within the distribution system.

6. **Post Treatment** - Post treatment typically includes degasification for carbon dioxide and hydrogen sulphide removal (if present), pH adjustment for corrosion control and chlorination.
7. **Reject Water** - Reject water may range from 25% to 50% of the raw water pumped to the reverse osmosis unit. This may present a problem both from the source availability and from the waste treatment capabilities. The amount of reject water from a unit may be reduced, to a limited extent, by increasing the feed pressure to the unit, however this may result in a shorter membrane life. Acceptable methods of waste disposal include discharge to the municipal sewer system provided it satisfies the regulatory requirements of the DOEC or to an evaporation pond.

8. **Cleaning the Membrane** - The osmosis membrane must be replaced or periodically cleaned with acid. Method of cleaning, and chemicals used must be approved by the DOEC. Care must be taken in the acid cleaning process to prevent contamination of both the raw and finished water system.

9. **Pilot Plant Study** - Prior to initiating the design of a reverse osmosis treatment facility, the DOEC should be contacted to determine if a pilot plant study would be required. In most cases, a pilot plant study will be required to determine the best membrane to use, the type of pretreatment, type of post treatment, the bypass ratio, the amount of reject water, process efficiency and other design criteria.

10. **Operator training and Start-up** - The ability to obtain qualified operators must be evaluated in selection of the treatment process. The necessary operator training shall be provided prior to plant start-up.

3.3.2.10. Bag and Cartridge Filters

Bag and cartridge technology has been used for some time in the food, pharmaceutical and industrial applications. This technology is increasingly being used by small public water supplies for treatment of drinking water.

The particulate loading capacity of these filters is low, and once expended the bag or cartridge filter must be discarded. This technology is designed to meet the low flow requirement needs of small systems. The operational and maintenance cost of bag and cartridge replacement must be considered when designing a system. These filters can effectively remove particles from water in the size range of Giardia cysts (5 to 10 microns) and Cryptosporidium (2 to 5 microns).

At the present time, filtration evaluation is based on Giardia cyst removal. However, consideration should be given to the bag or cartridge filter ability to remove particles in the size range of Cryptosporidium since this is a current public health concern.

With this type of treatment there is no alteration of water chemistry. Therefore, once the technology has demonstrated the 2-log removal efficiency, no further pilot demonstration is necessary. The demonstration of filtration is specific to a particular housing and a particular bag or cartridge filter. Any other combinations of different bags, cartridges, or housings will require additional demonstration of filter efficiency.

Treatment of surface water should include source water protection, filtration, and disinfection.

The following sub-sections should be considered in evaluating the applicability of bag or cartridge filtration.

3.3.2.10.1. Predesign/Design

1. The filter housing and bag/cartridge filter must demonstrate a filter efficiency of 2-log reduction in particles sized 2 micron and above. The DOEC will decide whether or not a pilot demonstration is necessary for each installation. This filtration efficiency may be accomplished by:

    a. Macroscopic particulate analysis, including particle counting, sizing and identification, which determines occurrence and removals of micro-organisms and other particles across a filter or system under ambient raw water source condition, or when artificially challenged.

    b. Giardia/Cryptosporidium surrogate particle removal evaluation in accordance with procedures specified in NSF Standard 53 or equivalent. These evaluations can be conducted by NSF or by another third-party whose certification would be acceptable to the DOEC.

    c. "Nonconsensus" live Giardia challenge studies that have been designed and carried out by a third-party agent recognized and accepted by the DOEC for interim evaluations. At the present time uniform protocol procedures for live Giardia challenge studies have not been established. If a live Giardia challenge study is performed on site there must be proper cross-connection control equipment in place and the test portion must be operated to waste.

    d. Methods other than these that are approved by the DOEC.

2. System components such as housing, bags, cartridges, membranes, gaskets, and O-rings should be evaluated under NSF Standard 61 or equivalent, for leaching of contaminants. Additional testing may be required by the DOEC.

3. The source water or pretreated water should have turbidity less than 5 NTU.

4. It is recommended that the flow rate through the treatment process be monitored. The flow rate through the bag/cartridge filter must not exceed 76 L/min, unless documentation at higher flow rates demonstrates that it will meet the requirement for removal of particles.

5. Pretreatment is strongly recommended. This will provide a more constant water quality to the bag/cartridge filter. Examples of pretreatment include media filter, larger opening bag/cartridge filter, infiltration galleries, and beach wells. Location of the water intake should be considered in the pretreatment evaluation.

6. Particle count analysis can be used to determine what level of pretreatment should be provided. It should be noted that particulate counting is a ‘snap shot’ in time and that there can be seasonal variations such as algae blooms, lake turnover, spring runoff, and heavy rainfall events that will give varied water quality.

7. It is recommended that chlorine or another disinfectant be added at the head of the treatment process to reduce/eliminate the growth of algae, bacteria, etc., on the filters. The impact on disinfection by-product formation should be considered.

8. A filter to waste component is strongly recommended, for any pretreatment pressure sand filters. At the beginning of each filter cycle and/or after every backwash of the pre-filters a set amount of water should be discharged to waste before water flows into the bag/cartridge filter.

9. If pressure media filters are used for pretreatment they must be designed according to Section 3.3.2.2.

10. A sampling tap shall be provided ahead of any treatment so a source water sample can be collected.

11. Pressure gauges and sampling taps shall be installed before and after the media filter, and before and after the bag/cartridge filter.

12. An automatic air release valve shall be installed on top of the filter housing.

13. Frequent start and stop operation of the bag or cartridge filter should be avoided. To avoid this frequent start and stop cycle the following options are recommended:

    a) A slow opening and closing valve ahead of the filter to reduce flow surges;

    b) Reduce the flow through bag or cartridge filter to as low as possible to lengthen filter run times; and

    c) Install a re-circulating pump that pumps treated water back to a point ahead of the bag or cartridge filter. Care must be taken to ensure there is no cross connection between the finished water and raw water.

14. A minimum of two bag or cartridge filter housings should be provided for water systems that must provide water continuously.

15. A pressure relief valve should be incorporated into the bag or cartridge filter housing.

16. Complete automation of the treatment system is not required. Automation of the treatment plant should be incorporated into the ability of the water system to monitor the finished water quality. It is important that a qualified water operator is available to run the treatment plant.

17. A plan of actions should be in place should the water quality parameters fail to meet the current requirements of the DOEC with respect to microbiological, physical, chemical and radiological qualities.

3.3.2.10.2. Operations

1. The filtration and backwash rates shall be monitored so that the pre-filters are being optimally used.

2. The bag and cartridge filters must be replaced when a pressure difference of 210 kPa or other pressure difference recommended by the manufacturer is observed. It should be noted that bag filters do not load linearly. Additional observation of the filter performance is required near the end of the filter fun.

3. Maintenance (o-ring replacement) shall be performed in accordance with the manufacturer's recommendations.

4. The following parameters should be monitored:
   a) Instantaneous flow rate;
   b) Total flow rate;
   c) Operating pressure;
   d) Pressure differential; and
   e) Turbidity.

3.3.3. Softening

Common processes for conventional water softening include lime, lime with soda ash, ion exchange, and combinations of these methods.

The softening process selected must be based upon the mineral qualities of the raw water and the desired finished water quality, in conjunction with requirements for disposal of sludge or brine waste, cost of plant, cost of chemicals and plant location. Applicability of the process chosen shall be demonstrated.

3.3.3.1. Lime or Lime - Soda Process

The process involves the thorough mixing of the chemicals with the water, followed by slow agitation to allow completion of the chemical reaction. Stabilization of the softened water is then required. This process cannot be expected to produce water with much less than 80 mg/L of hardness.

3.3.3.1.1. Chemicals

Either hydrated lime or quick lime is usually used in water softening, the choice depending on the availability of the chemicals and required equipment, together with the cost. Lime and recycled sludge should be fed directly into the rapid mix basin.

3.3.3.1.2. Reaction Basin

Designs standards for the reaction basin are as per those contained in Section 3.3.1.3.

Rapid mix basins must provide more than 30 seconds detention time with adequate velocity gradients to keep the lime particles dispersed.

3.3.3.1.3. Hydraulics

When split treatment is used, the bypass line should be sized to carry total plant flow, and an accurate means of measuring and splitting the flow must be provided.

3.3.3.1.4. Aeration

Determinations should be made for the carbon dioxide content of the raw water. When concentrations exceed 10 mg/L, the economics of removal by aeration as opposed to removal with lime should be considered if it has been determined that dissolved oxygen in the finished water will not cause corrosion problems in the distribution system. (See Section 3.3.4)

3.3.3.1.5. Stabilization

In the softening process the addition of lime to water reduces the carbonate saturation index and increases the tendency of the water to deposit calcium carbonate. The carbonate balance may be partly or completely restored by stabilization of the softened water. This can be achieved by the addition of carbon dioxide, acid or polyphosphates.

1. **Carbon Dioxide:**

   For treated waters with pH over 9.5 during treatment, two-stage recarbonation equipment should be considered. Single stage recarbonation ahead of filtration will probably be sufficient for treated waters with a pH below 9.5. The recarbonation basin should have a water depth of approximately 2.5 m and provide a detention time of between 3 and 10 min.

   Adequate precaution must be taken to prevent the possibility of carbon monoxide entering the plant from recarbonation compartments. Adequate ventilation should be provided.

2. **Acid:**

   Acid should be fed in concentrated solution ahead of the filters. Feed equipment should be located as close to the point of application as possible. Adequate precautions shall be taken for safety, such as not adding water to the concentrated acid.

3. **Polyphosphates:**

   Several types of polyphosphates, containing variable amounts of alkali are available for stabilization. The stock solutions should be kept covered, and should contain satisfactory chlorine residuals of approximately 10 mg/L.

3.3.3.1.6. Sludge Collection and Disposal
Mechanical sludge removal equipment shall be provided in the sedimentation basin, and sludge recycling to the rapid mix should be provided.

Provision must be included for the proper disposal of softening sludge (see Section 3.3.12)

3.3.3.1.7. Disinfection
The use of excess lime shall not be considered an acceptable substitute for disinfection (See Section 4)

3.3.3.1.8. Plant Start-up
The plant processes must be manually started following shutdown.

3.3.3.2. Cation Exchange Process
The mineral quality of the raw water must be considered when softening by this method; the process does not reduce the total solids content but merely substitutes sodium in the hardness-causing compounds.

Alternative methods of hardness reduction should be investigated when the sodium content and dissolved solids concentration is of concern. Iron, manganese, or a combination of the two, should not exceed 0.3 mg/L in the water as applied to the ion exchange resin.

Waters having turbidity of 5 NTUs or more should not be applied directly to cation-exchange softeners. Waters with a pH above 8.4 should not be applied to silica gel materials. Waters containing less than 12 mg/L of silica as silicon dioxide should not be applied to siliceous cation material. When the applied water contains a chlorine residual, the ion-exchange materials should be of a type that is not damaged by residual chlorine. Phenolic resin exchange materials shall not be used unless approved methods are utilized for disinfecting the material prior to use.

3.3.3.2.1. Design
Where bacterial removal is not involved, ion-exchange softeners may be of either the pressure or open gravity type. When open gravity units are used, the water should be chlorinated. Either upflow or downflow units may be used. Automatic regeneration is highly desirable when only part-time attendance is to be provided. Raw waters containing turbidity, suspended matter, dissolved iron or manganese, high concentrations of certain salts, and particularly any substances deleterious to the exchange materials, should be treated before softening.

3.3.3.2.2. Capacity
The design capacity for hardness removal should not exceed 48,000 mg/L when resin is regenerated with 2.l kg of salt per l kg of hardness removed.

3.3.3.2.3. Depth of Resin
The depth of the exchange resin should not be less than 0.9 m.

3.3.3.2.4. Rate of Flow

The rate of flow through a softening unit should not exceed 17 m/hr. The rate of backwash should be between 14 to 20 m/hr of bed area. Rate-of-flow controllers, or the equivalent, must be installed for the above purposes.

3.3.3.2.5. Freeboard

The freeboard will depend on the specific gravity of the resin and the direction of water flow. Generally, the washwater collector should be 0.6 m above the top of the resin on downflow units.

3.3.3.2.6. Underdrains and Supporting Gravel

The bottoms, strainer systems and support for the exchange resin should conform to the criteria provided for rapid rate gravity filters (see Section 3.3.2.1).

3.3.3.2.7. Distribution of Brine

Facilities should be included for even distribution of the brine over the entire surface of both upflow and downflow units.

3.3.3.2.8. Cross-connection Control

Backwash, rinse and air relief discharge pipes should be installed in such a manner as to prevent any possibility of back-siphonage.

3.3.3.2.9. Bypass

A bypass shall be provided around all softening units to produce a blended water of the desired hardness. Totalizing meters should be installed on the bypass line and on each softener unit. An automatic proportioning or regulating device, and shut-off valve should be provided on the bypass line. In some installations, it may be necessary to treat the bypassed water to obtain acceptable levels of iron and/or manganese in the finished water.

3.3.3.2.10. Additional Limitations

Silica gel resins should not be used for waters having a pH above 8.4 or containing less than 6.0 mg/L silica and should not be used when iron is present. When the applied water contains a chlorine residual, the cation exchange resin shall be a type that is not damaged by residual chlorine. Phenolic resin should not be used.

3.3.3.2.11. Wet Salt Storage Tanks and Brine Tanks

1. Wet salt storage and salt dissolving or brine tanks must be covered, corrosion resistant, and be equipped with manhole or hatchway openings having raised curbs and watertight covers with overlapped edges similar to those required for finished water reservoirs.

2. Overflow pipes should be turned downward, have a free fall discharge or a self-closing flap valve, and be covered with a small corrosion resistant mesh screen.

3. Wet salt storage tanks should have sufficient capacity to store 1.5 carloads or 1.5 truckloads (depending on method of delivery) of salt in order to permit refill before a tank is completely empty. Alternately, two wet salt storage tanks or compartments designed to operate independently should be provided.

4. Water for filling a tank should be distributed over the entire surface of the tank by pipes above the maximum brine level in the tank. The salt should be supported on graduated layers of gravel under which there is half tile or other suitable means of collecting the brine.

5. Salt storage capacity should generally be adequate for at least one month.

6. A brine-measuring tank should have a capacity in excess of that required for regeneration of one unit.

7. An injector may be used to transfer brine from the brine tank to the softeners. If a pump is used, a brine-measuring tank or means of metering should be provided to obtain proper dilution.
8. Consideration should be given to the advisability of disinfecting the brine when the quality of the salt may be inferior, or the method of handling is questionable.

3.3.3.2.12. Stabilization
The need for corrective treatment should be determined. Soda ash, caustic soda, caustic silicate, polyphosphates or a combination of these, or other alkali may be added to the softened (or blended) water. Positive displacement solution feed pumps, coordinated with the softening units, should be used.

3.3.3.2.13. Sampling Taps
Smooth-nosed sampling taps should be provided for the collection of representative samples for both bacteriological and chemical analyses. The taps should be located to provide for sampling of the softener influent and of the blended water when any hard water is bypassed. The blended water-sampling tap should be at least 6 m downstream from the point of blending in order to assure a representative sample. Petcocks are not acceptable as sampling taps. Sampling taps should be provided on the brine tank discharge piping.

3.3.3.2.14. Waste Disposal
The DOEC shall be consulted, and its approval obtained concerning the disposal of brine wastes.

3.3.3.2.15. Construction Materials
Pipes and contact materials must be resistant to the aggressiveness of salt. Plastic and red brass are acceptable piping materials. Steel and concrete must be coated with a non-leaching protective coating, which is compatible with salt and brine.

3.3.3.2.16. Housing
Bagged salt and dry bulk salt storage shall be enclosed and separated from other operating areas in order to prevent damage to equipment.

3.3.3.3. Water Quality Test Equipment
Test equipment for alkalinity, total hardness, carbon dioxide content, and pH should be provided to determine treatment effectiveness.

3.3.4. Aeration

Aeration may be used to reduce or remove objectionable amounts of carbon dioxide, hydrogen sulphide, methane, tastes and odours, and to introduce oxygen to assist in iron and/or manganese removal. Local conditions, the quality of the water to be treated, and the cost should be carefully considered before deciding on the type of aeration. The packed tower aeration process is an aeration process applicable to removal of volatile organic contaminants.

3.3.4.1. Natural Draft Aeration

The design shall provide:

1. Discharge through a series of three or more trays with separation of the trays between 300 and 375 mm;
2. Perforations in the distribution pan that are 5 mm to 12 mm in diameter and spaced at 25 mm to 75mm on centres to maintain a 250 mm water depth;
3. Media, when used on the trays, should be structurally sound crushed rock, slag or specially manufactured material, from 75 mm to 100 mm in size;
4. For distribution of water uniformly over the top tray;
5. Loading at a rate of 0.68 to 3.4 L/sec/m^2 of total tray area;
6. Trays with slotted, heavy wire (12 mm openings) mesh or perforated bottoms;
7. Construction of durable material resistant to aggressiveness of the water and dissolved gases;
8. Protection from loss of spray water by wind carriage by enclosure with louvers sloped to the inside at an angle of approximately 45 degrees; and
9. Protection from insects by 24-mesh screen.

3.3.4.2. Forced or Induced Draft

Devices shall be designed to provide the following:

1. An insect and light proof enclosure constructed of steel, wood, or other durable material;
2. A ventilating blower or fan having a weatherproof motor in a tight housing with a screened air inlet. The air outlet of the aerator should be turned down and screened;
3. Wood slats, trays or other devices should be located in the enclosure to provide adequate water distribution for air contact;
4. Aerator can be easily reached or removed for maintenance of the interior, or installed in a separate aerator room;

5. Aerator to be located in an area as free as possible from obnoxious fumes, dust and dirt;

6. Provide loading at a rate of 0.68 to 3.4 L/sec/m^2 of total tray area;

7. Ensure that the water outlet is adequately sealed to prevent unwarranted loss of air;

8. Discharge through a series of five or more trays with separation of trays not less that 150 mm;

9. Distribution of water uniformly over the top tray; and

10. Be of durable material resistant to the aggressiveness of the water and dissolved gases.

3.3.4.3. Spray Aeration

Design shall provide:

1. A hydraulic head of between 1.5 and 7.5 m;

2. Nozzles, with the size, number, and spacing of the nozzles being dependent on the flowrate, space, and the amount of head available;

3. Nozzle diameter in the range of 12 to 17 mm to minimize clogging, and

4. An enclosed basin to contain the spray. Any opening for ventilation, etc. must be protected with a 24-mesh screen.

3.3.4.4. Pressure Aeration

Pressure aeration may be used for oxidation purposes only if pilot plant study indicates the method is applicable. It is not acceptable for removal of dissolved gases. Filters following pressure aeration must have adequate exhaust devices for release of air. Pressure aeration devices shall be designed to:

1. Give thorough mixing of compressed air with water being treated, and

2. Provide screened and filtered air, free of obnoxious fumes, dust, dirt and other contaminants.

3.3.4.5. Packed Tower Aeration

Packed tower aeration (PTA), which is also known as air stripping, involves passing water down through a column of packing material while pumping air counter-currently up through the packing. PTA is used for the removal of volatile organic chemicals, THMs, carbon dioxide, and radon. Generally, PTA is feasible for compounds with a Henry's Constant greater than 100 (expressed in atm mol/mol) - 12º C), but is not normally feasible for removing compounds with a Henry's Constant less than 10. For values between 10 and 100, PTA may be feasible but should be extensively evaluated using pilot studies. Values for Henry's Constant should be discussed with the DOEC prior to final design.

3.3.4.5.1. Process Design

1. Process design methods for PTA involve the determination of Henry's Constant for the contaminant, the mass transfer coefficient, air pressure drop and stripping factor. The applicant shall provide justification for the design parameters selected (i.e. height and diameter of unit, air to water ratio, packing depth, surface loading rate, etc.). Pilot plant testing shall be provided. The pilot test shall evaluate a variety of loading rates, and air to water ratios at the peak contaminant concentration. Special consideration should be given to removal efficiencies when multiple contaminations occur. Where there is considerable past performance data on the contaminant to be treated and there is a concentration level similar to previous projects, the DOEC may approve the process design based on use of appropriate calculations without pilot testing. Proposals of this type must be discussed with the DOEC prior to the submission of any permit applications.

2. The tower shall be designed to reduce contaminants to below the maximum contaminant level (MCL) and to the lowest practical level.

3. The ratio of the column diameter to packing diameter should be at least 7:1 for the pilot unit and at least 10:1 for the full-scale tower. The type and size of the packing used in the full-scale unit shall be the same as that used in the pilot work.

4. The minimum volumetric air to water ratio at peak water flow should be 25:1. The maximum air to water ratio for which credit will be given is 80:1.

5. The design should consider potential fouling problems from calcium carbonate and iron precipitation and from bacterial growth. It may be necessary to provide pretreatment. Disinfection capability shall be provided prior to and after PTA.

6. The effects of temperature should be considered since a drop in water temperature can result in a drop in contaminant removal efficiency.

3.3.4.5.2. Materials of Construction

1. The tower can be constructed of stainless steel, concrete, aluminum, fibreglass or plastic. Uncoated carbon steel is not recommended because of corrosion. Towers constructed of lightweight materials should be provided with adequate support to prevent damage from wind.

2. Packing materials shall be resistant to the aggressiveness of the water, dissolved gases and cleaning materials, and shall be suitable for contact with potable water.

3.3.4.5.3. Water Flow System

1. Water should be distributed uniformly at the top of the tower using spray nozzles or orifice-type distributor trays that prevent short-circuiting. For multi-point injection, one injection point for every 190 cm^2 of tower cross-sectional area is recommended.

2. A mist eliminator shall be provided above the water distribution system.

3. A side wiper redistribution ring should be provided at least every 3 m in order to prevent water channelling along the tower wall and short-circuiting.

4. Sample taps shall be provided in the influent and effluent piping.

5. The effluent sump, if provided, shall have easy access for cleaning purposes and be equipped with a drain valve. The drain shall not be connected directly to any storm or sanitary sewer.

6. A blow-off line should be provided in the effluent piping to allow for discharge of water/chemicals used to clean the tower.

7. The design shall prevent freezing of the influent riser and effluent piping when the unit is not operating. If piping is buried, it shall be maintained under positive pressure.

8. The water flow to each tower shall be metered.

9. An overflow line shall be provided with discharges located 300 to 350 mm above a splash pad or drainage inlet. Proper drainage shall be provided to prevent flooding of the area.

10. Butterfly valves may be used in the water effluent line for better flow control, as well as to minimize air entrainment.

11. Means shall be provided to prevent flooding of the air blower.

12. The water influent pipe should be supported separately from the tower's main structural support.

3.3.4.5.4. Air Flow System

1. The air inlet to the blower and the tower discharge vent shall be down turned and protected with a non-corrodible 24-mesh screen to prevent contamination from extraneous matter. It is recommended that a 4-mesh screen also be installed prior to the 24-mesh screen on the air inlet system.

2. The air inlet shall be in a protected location.

3. An air flow meter shall be provided on the influent air line, or an alternative method to determine the air flow shall be provided.

4. A positive air flow sensing device and a pressure gauge must be installed on the air influent line. The positive air flow sensing device must be a part of an automatic control system, which will turn off the influent water if positive air flow is not detected. The pressure gauge will serve as an indicator of fouling build-up.

5. A backup motor for the air blower must be readily available.

3.3.4.5.5. Other Features

Other features that shall be provided:

1. A sufficient number of access ports with a minimum diameter of 0.6 m to facilitate inspection, media replacement, media cleaning and maintenance of the interior.

2. A method of cleaning the packing material when iron, manganese, or calcium carbonate fouling may occur.

3. Tower effluent collection and pumping wells constructed to clearwell standards.

4. Provisions for extending the tower height without major reconstruction.

5. An acceptable alternative supply must be available during periods of maintenance and operation interruptions. No bypass shall be provided unless specifically approved by the DOEC.

6. Disinfection application points both ahead of and after the tower to control biological growth.

7. Disinfection and adequate contact time after the water has passed through the tower and prior to the distribution system.

8. Adequate packing support to allow free flow of water and to prevent deformation with deep packing heights.

9. Operation of the blower and disinfectant feeder equipment during power failures.

10. Adequate foundation to support the tower and lateral support to prevent overturning due to wind loading.

11. Fencing and locking gate to prevent vandalism.

12. An access ladder with safety cage for inspection of the aerator including the exhaust port and de-mister.

13. Electrical interconnection between blower, disinfectant feeder and well pump.

3.3.4.5.6. Environmental Factors

1. The applicant must contact the DOEC to determine if permits are required.

2. Noise control facilities should be provided on PTA systems located in residential areas.

3.3.4.6. Other Methods of Aeration

Other methods of aeration may be used if applicable to the treatment needs. Such methods include, but are not restricted to, spraying, diffused air, cascades and mechanical aeration. The treatment processes must be designed to meet the particular needs of the water to be treated and are subject to the approval of the DOEC.

3.3.4.7. Protection of Aerators

All aerators except those discharging to lime softening or clarification plants shall be protected from contamination by birds, insects, wind borne debris, rainfall and water draining off the exterior of the aerator.

3.3.4.8. General Design

3.3.4.8.1. Wind Protection

Spray aerators should be enclosed between walls or a louvered fence, the louvers being sloped down to the inside at an angle of approximately 45 degrees.

3.3.4.8.2. Disinfection

Groundwater supplies exposed to the atmosphere by aeration must receive chlorination as the minimum additional treatment.

3.3.4.8.3. Bypass

A bypass should be provided for all aeration units except those installed to comply with maximum contaminant levels.

3.3.4.8.4. Contamination

Waters, which do not require additional treatment, should be protected by a non-corrodible fine screen. A water, dirt, and dust tight roof should cover the aerator.

3.3.4.8.5. Corrosion Control

The aggressiveness of the water after aeration should be determined and corrected by additional treatment, if necessary.

Internal and external corrosion of a public water supply distribution system is a recognized problem that cannot be completely eliminated but can be effectively controlled. Aside from the economic and aesthetic problems, the possible adverse health effects of corrosion products, such as lead and copper, is a major consideration

Corrosion of metallic pipes is an electrochemical process by which the pipe material is chemically oxidized. This can occur as a result of heterogeneity of dissimilar metals, creating electrical potential or by the attacking of the interior walls of the pipe by aggressive molecules in the water.

Control of corrosion is a function of the design, maintenance, and operation of a public water supply. These functions must be considered simultaneously in order for the corrosion control program to function properly. Corrosion problems must be solved on an individual basis depending on the specific water quality characteristics and materials used in the distribution system. Specific information can be obtained from publications of technical agencies and associations such as USEPA (<u>Lead and Copper Regulations</u>, 1994) and the American Water Works Association (<u>Lead and Copper Strategies</u>, 1990; <u>Chemistry of Corrosion Inhibitors in Potable Waters</u>, 1990). Broad areas of consideration for a corrosion control program follow.

The following apply for internal corrosion:

1. Provide for a system of records by which the nature and frequency of corrosion problems are recorded. On a schematic of the distribution system, show the location of each problem so that follow-up investigations and improvements can be made when a cluster of problems is identified.

2. When complaints are received from a customer, follow up with an inspection by experienced personnel or consultant experienced in corrosion control. Where advisable, obtain samples of water using appropriate sampling protocols for chemical and microbiological analyses and piping and plumbing material samples. Analyses should be made to determine the type and, if possible, the cause of the corrosion.

3. Establish a program or conduct desktop analyses or loop studies to determine the corrosiveness/determination of the stability of the water in representative parts of the distribution system. Analysis for alkalinity, pH, temperature, and corrosion products (such as lead, cadmium, copper, and iron) should be performed on water samples collected at the treatment plant or wellhead, and at representative points in the distribution system. In comparing the analyses of the source water with the distribution system water, significant changes in alkalinity, pH, or corrosion products would indicate that corrosion is taking place, and thereby indicate that corrective steps need to be taken.

4. Where possible, especially when corrosion has been detected in the determination of water stability, provide a program that will measure both the physical and chemical aspects of the corrosion phenomena. Physical measurement of the rate of corrosion can be made by the use of coupons, easily removed sections of pipe, connected flow-through pipe test sections, or other piping using desktop analyses or corrosion indices such as the Langelier Index, Byznar Index, or Aggressiveness Index (AWWA C-400). Correlation of the data from the physical measurement with the data from the selected corrosion analysis will provide information to determine the type of corrective treatment needed and may allow for the subsequent use of the corrosion analysis alone to determine the degree of corrosivity in select areas of the distribution system.

5. If corrosion is found to exist throughout the distribution system, corrective measures at the treatment plant, pump station or wellhead should be initiated. A chemical feed can be made to provide a stable to slightly depositing water or water quality, which mitigates the solubility of targeted parameters. In calculating the stability index and the corresponding chemical feed adjustments, consideration must be given to items such as: the water temperature, if it varies with the season and within various parts of the distribution system; the velocity of flow within various parts of the distribution system; the degree of stability needed by the individual customer; and the dissolved oxygen content of distributed water, especially in water having low hardness and alkalinity. Threshold treatment involving the feeding of a ortho or blended phosphate or a silicate to control corrosion may be considered for both ground and surface water supplies.

6. Additional control of corrosion problems can be obtained by a regulation or ordinance for the materials used in or connected to a distribution system. Careful selection of material compatible with the physical system or the water being delivered can aid in reduction of corrosion product production.

Note: Adjustment of pH for corrosion control must not interfere with other pH dependent processes (e.g., colour removal by alum coagulation) or aggravate other water quality parameters (e.g., THM formation). In addition, the use of ortho- or blended phosphates should not aggravate distribution microbial concerns or adversely impact wastewater facilities.

3.3.4.8.6. Quality Control
Equipment should be provided to test for DO, pH, and temperature to determine proper functioning of the aeration device. Equipment to test for iron, manganese, and carbon dioxide should also be considered.

3.3.5. Iron And Manganese Removal

Iron and manganese control refers solely to the treatment processes designed specifically for this purpose. The treatment process used will depend upon the character of the raw water. The selection of one or more treatment processes must meet specific local conditions as determined by engineering investigations, including chemical analysis of representative samples of water to be treated, and receive the approval of the DOEC. It may be necessary to operate a pilot plant in order to gather all information pertinent to the design. Consideration should be given to adjusting pH of the raw water to optimize the chemical reaction. Testing equipment and sampling taps shall be provided as outlined in Sections 3.1.7 and 3.1.9

3.3.5.1. Removal by Oxidation, Detention and Filtration

3.3.5.1.1. Oxidation
Oxidation may be by aeration, as indicated in Section 3.3.4, or by chemical oxidation with chlorine, potassium permanganate, ozone or chlorine dioxide.

3.3.5.1.2. Detention
1. **Reaction** – A minimum detention time of 30 minutes shall be provided following aeration to ensure that the oxidation reactions are as complete as possible. This minimum detention may be omitted only when a pilot plant study indicates no need for detention. The detention basin may be designed as a holding tank without provisions for sludge collection but with sufficient baffling to prevent short-circuiting.

2. **Sedimentation** - Sedimentation basins shall be provided for treated water with high iron and/or manganese content, or where chemical coagulation is used to reduce the load on the filters. Provisions for sludge removal shall be made.

3.3.5.1.3. Filtration
Filters shall be provided and shall conform to Section 3.3.2.

3.3.5.2. Removal by Lime - Soda Softening Process

See Section 3.3.3.1.

3.3.5.3. Removal by Manganese Coated Media Filtration

This process consists of a continuous feed of potassium permanganate to the influent of a manganese coated media filter.

1. Provisions should be made to apply the permanganate as far ahead of the filter as practical and to a point immediately before the filter.

2. Other oxidizing agents or processes such as chlorination or aeration may be used prior to the permanganate feed to reduce the cost of the chemical.

3. An anthracite media cap of at least 150 mm shall be provided over manganese coated media.

4. Normal filtration rate is 7.2 m/hr.

5. Normal wash rate is 20 to 24 m^3/hr for manganese greensand and 37 to 49 m^3/hr for manganese coated media.

6. Air washing should be provided.

7. Sample taps shall be provided:
   a. Prior to application of permanganate;
   b. Immediately ahead of filtration;
   c. At the filter effluent; and
   d. At points between the anthracite media and the manganese coated media.

3.3.5.4. Removal by Units Regenerated with Potassium Permanganate

Iron and manganese, which can be oxidized by aeration, may be removed by passing the water through exchange media, regenerating the media with potassium permanganate. Pressure units may be used for this type of treatment. The rate through such units should not exceed 2.0 L/m^2s. Care should be taken not to aerate the water before it enters the exchange unit.

3.3.5.5. Removal by Ion Exchange

This process of iron and manganese removal should not be used for water containing more than 0.3 mg/L of iron, manganese or combination thereof. This process is not acceptable where either the raw water or wash water contains dissolved oxygen or other oxidants.

3.3.5.6. Sequestration by Polyphosphates

This process shall not be used when iron, manganese or combination thereof exceeds 1.0 mg/L. The total phosphate applied shall not exceed 10 mg/L as PO_4. Where phosphate treatment is used, satisfactory chlorine residuals shall be maintained in the distribution system. Possible adverse affects on corrosion must be addressed when phosphate addition is proposed for ion sequestering.

1. Feeding equipment shall conform to the requirements of Section 3.4.

2. Stock phosphate solution must be kept covered and disinfected by carrying approximately 10 mg/L free chlorine residual. Phosphate solutions having a pH of 2.0 or less may be exempted from this requirement by the DOEC.

3. Polyphosphates shall not be applied ahead of iron and manganese removal treatment. The point of application shall be prior to the aeration, oxidation or disinfection, if no iron or manganese removal treatment is provided.

3.3.5.7. Sequestration by Sodium Silicates

Sodium silicate sequestration of iron and manganese is appropriate only for groundwater supplies prior to air contact. On-site pilot tests are required to determine the suitability of sodium silicate for the particular water and the minimum feed needed. Rapid oxidation of the metal ions, such as by chlorine or chlorine dioxide, must accompany or closely precede the sodium silicate addition. Injection of sodium silicate more than 15 seconds after oxidation may cause detectable loss of chemical efficiency. Dilution of feed solutions much below 5% silica as SO_2 should also be avoided for the same reason.

1. Sodium silicate addition is applicable to waters containing up to 2 mg/L of iron, manganese or combination thereof.

2. Chlorine residuals shall be maintained throughout the distribution system to prevent biological breakdown of the sequestered iron.

3. The amount of silicate added shall be limited to 20 mg/L as SiO_2, but the amount of added and naturally occurring silicate shall not exceed 60 mg/L as SiO_2.

4. Feeding equipment shall conform to the requirements of Section 3.4.

5. Sodium silicate shall not be applied ahead of iron or manganese removal treatment.

3.3.5.8. Sampling Taps

Smooth-nosed sampling taps shall be provided for control purposes. Taps shall be located on each raw water source, each treatment unit influent, and each treatment unit effluent.

3.3.5.9. Testing Equipment

1. The equipment should have the capacity to accurately measure the iron content to a minimum of 0.1 mg/L, and the manganese content to a minimum of 0.05 mg/L.

2. Where polyphosphate sequestration is practiced, appropriate phosphate testing equipment shall be provided.

3.3.6. Nitrate Removal Using Sulphate Selective Anion Exchange Resin

Four treatment processes are generally considered acceptable for Nitrate/Nitrite removal. These are anion exchange, reverse osmosis, nanofiltration and electrodialysis. Although these treatment processes, when properly designed and operated, will reduce the nitrate/nitrite concentration of the water to acceptable levels, primary consideration shall be given to reducing the nitrate/nitrite levels of the raw water through either obtaining water from an alternate water source or through watershed management. Reverse osmosis, nanofiltration or electrodialysis should be investigated when the water has high levels of sulphate or when the chloride content or dissolved solids concentration is of concern.

Most anion exchange resins used for nitrate removal are sulphate selective resins. Although nitrate selective resins are available, these resins typically have a lower total exchange capacity.

3.3.6.1. Special Caution

If a sulphate selective anion exchange resin is used beyond bed exhaustion, the resin will continue to remove sulphate from the water by exchanging the sulphate for previously removed nitrates resulting in treated water nitrate levels being much higher than raw water levels. Therefore, it is extremely important that the system not be operated beyond design limitations.

3.3.6.2. Pretreatment Requirement

An evaluation shall be made to determine if pretreatment of the water is required if the combination of iron, manganese, and heavy metals exceeds 0.1 mg/L.

3.3.6.3. Design

Anion exchange units are typically of the pressure type, down flow design. Although a pH spike can typically be observed shortly before bed exhaustion, automatic regeneration based on volume of water treated should be used unless justification for alternate regeneration is submitted to and approved by the DOEC. A manual override shall be provided on all automatic controls. A minimum of two units must be provided. The total treatment capacity must be capable of producing the maximum daily water demand at a level below the nitrate/nitrite MCL. If a portion of the water is bypassed around the unit and blended with the treated water, the maximum blend ratio allowable must be determined based on the highest anticipated raw water nitrate level. If a bypass is provided, a totalling meter and a proportioning or regulating valves must be provided on the bypass line.

3.3.6.4. Exchange Capacity

Anion exchange media will remove both nitrates and sulphate from the water being treated. The design capacity for nitrate and sulphate removal expressed as $CaCO_3$ should not exceed 565 grains per litre when the resin is regenerated with 0.545 kg of salt per cubic foot (160) g/l) of resin when operating at 0.27 to 0.4 L/min/L. However, if high levels of chlorides exist in the raw water, the exchange capacity of the resin should be reduced to account for the chlorides.

3.3.6.5. Flow Rates

The treatment flow rate should not exceed 29 to 32 cm/min down flow rate. The back wash flow rate should be 8 to 12 cm/min, with a fast rinse approximately equal to the service flow rate.

3.3.6.6. Freeboard

Adequate freeboard must be provided to accommodate the backwash flow rate of the unit.

3.3.6.7. Miscellaneous Appurtenances

The system shall be designed to include an adequate under drain and supporting gravel system, brine distribution equipment, and cross connection control.

3.3.6.8. Monitoring

Whenever possible, the treated water nitrate/nitrate level should be monitored using continuous monitoring and recording equipment. The continuous monitoring equipment should be equipped with a high nitrate level alarm. If continuous monitoring and recording equipment is not provided, the finished water nitrate/nitrite levels must be determined (using a test kit) no less than daily, preferably just prior to regeneration of the unit.

3.3.6.9. Waste Disposal

Generally, waste from the anion exchange unit should be disposed in accordance with Section 3.3.12. However, prior to any discharge, the DOEC must be contacted for wastewater discharge limitation.

3.3.6.10. Additional Limitations

Certain types of anion exchange resins can tolerate no more than 0.05 mg/L of free chlorine. When the applied water will contain a chlorine residual, the anion exchange resin must be a type that is not damaged by residual chlorine.

3.3.7. Taste and Odour Control

Provision shall be made for the control of taste and odour at all surface water treatment plants. Chemicals shall be added sufficiently ahead of other treatment processes to ensure adequate contact time for an effective and economical use of the chemicals. Where severe taste and odour problems are encountered, in-plant and/or pilot plant studies are required.

3.3.7.1. Flexibility

Plants treating water that is known to have taste and odour problems should be provided with equipment that makes several of the control processes available so that the operator will have flexibility in operation.

3.3.7.2. Chlorination

Chlorination can be used for the removal of some objectionable odours. Adequate contact time must be provided to complete the chemical reactions involved. Excessive potential by-product production through this process should be avoided by adequate bench-scale testing prior to design.

3.3.7.3. Chlorine Dioxide

Chlorine dioxide has been generally recognized as a treatment for tastes caused by industrial wastes, such as phenols. However, chlorine dioxide can be used in the treatment of any taste and odour that is treatable by an oxidizing compound. Provisions should be made for proper storing and handling of the sodium chlorite, so as to eliminate any danger of explosion.

3.3.7.4. Powdered Activated Carbon

1. Powdered activated carbon should be added as early as possible in the treatment process to provide maximum contact time. Flexibility to allow the addition of carbon at several points is preferred. Activated carbon should not be applied near the point of chlorine or other oxidant application.

2. The carbon can be added as a pre-mixed slurry or by means of a dry-feed machine as long as the carbon is properly wetted.

3. Continuous agitation or re-suspension equipment is necessary to keep the carbon from depositing in the slurry storage tank.

4. Provision shall be made for adequate dust control.

5. The required rate of feed of carbon in a water treatment plant depends upon the tastes and/or odours involved, but provision should be made for adding from 0.l mg/L to at least 40 mg/L.

6. Powdered activated carbon shall be handled as a potentially combustible material. It should be stored in a building or compartment as nearly fireproof as possible. Other chemicals should not be stored in the same compartment. A separate room should be provided for carbon feed installations. Carbon feeder rooms should be equipped with explosion-proof electrical outlets, lights and motors.

3.3.7.5. Granular Activated Carbon

See Section 3.3.2.1.6 for application within filters.

3.3.7.6. Copper Sulphate and Other Copper Compounds

Continuous or periodic treatment of water with copper compounds to kill algae or other growths shall be controlled to prevent copper in excess of 1.0 mg/L as copper in the plant effluent or distribution system. Care shall be taken to ensure an even distribution. Approval for the dosage proposed must be obtained from the DOEC. For continuous feeding, copper compounds should be added by machine or solution-feed equipment. In large reservoirs, the chemical can be added from a boat by dragging bags of the chemical, by chemical sprayers or by using dry-feed or solution-feed machines.

3.3.7.7. Aeration

See Section 3.3.4.

3.3.7.8. Potassium Permanganate

Application of potassium permanganate may be considered, providing the treatment shall be designed so that the products of the reaction are not visible in the finished water.

3.3.7.9. Ozone

Ozonation can be used as a means of taste and odour control. Adequate contact time must be provided to complete the chemical reactions involved. Ozone is generally more desirable for treating water with high threshold odours.

3.3.7.10. Other Methods for Taste and Odour Control

The decision to use any other methods of taste and odour control should be made only after careful laboratory tests and/or pilot plant tests, and in consultation with the DOEC.

3.3.8. Fluoridation

3.3.8.1. Approval of Fluoridation Program

Proposals for fluoridation shall be submitted to the DOEC for approval. The proposal shall include:

1. Written endorsement or resolution of the local medical and dental societies and the local health authorities;

2. Submission of an appropriate fluoridation bylaw by the local government describing the condition, timing and general regulations that will be applied;

3. Detailed specifications for the chemical feeding equipment to be used;

4. Detailed plans showing the location of the equipment, piping layout, manner of control, and point of fluoride application;

5. Statement of the chemical to be used with quantitative analysis;

6. Plans for storage of the chemical to be used;

7. Plans for dust control facilities; and

8. Appraisal and approval of the qualifications of the personnel who will make the analyses to control the application of fluorides.

3.3.8.2. Fluoride Compounds

Various compounds are available and include sodium fluoride, sodium silicofluoride, ammonium silicofluoride and hydro-fluosilicic acid. The fluoride compounds shall conform to the applicable AWWA standards.

3.3.8.3. Fluoride Storage Facilities

Fluoride chemicals should be isolated from other chemicals to prevent contamination. The fluoride chemicals should be stored in covered or unopened shipping containers, unless the chemical is transferred into an approved covered storage unit and away from acids. Storage units directly supplying feeders should have sufficient capacity for one day's dosage at the average daily demand. Chemicals must be stored in a reasonably dry space. Storage units for large quantities of hydro-fluorosilicic acid should be vented to the atmosphere.

3.3.8.4. Chemical Feeders

1. Chemical feeders should be selected to meet specific requirements and hydraulic conditions. The accuracy should be within 5% of the intended dosage. Scales, loss-of-weight recorders or liquid level indicators shall be provided for chemical feeds.

2. Where the rate of flow of the water being treated varies over short intervals of time, the feeder should dose in proportion to the flow. Scales or loss-of-mass recorders should be provided.

3. The floor surfaces surrounding the feeders should be smooth and impervious.

4. Fluoride compound shall not be added before lime-soda softening or ion exchange softening.

5. The point of application of fluorosilicic acid, if into a horizontal pipe, shall be in the lower half of the pipe.

6. A fluoride solution shall be applied by a positive displacement pump having a stroke rate not less than 20 strokes per minute.

7. A spring opposed diaphragm type anti-siphon device shall be provided for all fluoride feed lines and dilution water lines.

8. A device to measure the flow of water to be treated is required.

9. The dilution water pipe shall terminate at lease two pipe diameters above the solution tank.

10. Water used for sodium fluoride dissolution shall be softened if hardness exceeds 75 mg/L as calcium carbonate.

11. Fluoride solutions shall be injected at a point of continuous positive pressure or a suitable air gap provided.

12. The electric outlet used for the fluoride feed pump should have a non-standard receptacle and shall be interconnected with the well or service pump.

13. Saturators shall be of the upflow type and be provided with a meter and backflow protection on the makeup water line.

The following apply to dry chemical feeders:

1. Dry chemical feeders of either the volumetric or gravimetric type are acceptable.

2. Dry chemical feeders must be completely enclosed and precautions for dust prevention shall be taken.

3. Water should be fed to the solution pot so as to prevent back-siphonage into the water supply. A vacuum breaker or its equivalent should be provided to prevent the solution from being drained or siphoned into the water supply when the unit is shut down.

4. There should be no direct connection between any sewer and the drain of a solution pit.

5. Any booster pump used to force the solution into the water should be constructed of a material not subject to chemical attack (e.g. bronze).

3.3.8.5. Protective Equipment

The following shall be provided for each operator:

1. At least one pair of rubber gloves with long gauntlet;

2. A dust respirator of a type approved by the DOEC for toxic dusts;

3. An apron or other protective clothing;

4. Goggles or face mask; and

5. Other protective equipment must be provided as necessary.

3.3.8.6. Dust Control

1. Provision should be made for the disposal of empty bags, drums or barrels, by approved methods that will minimize exposure to fluoride dusts.

2. A metal wheelbarrow should be available for the temporary handling of punctured bags.

3. Provision should be made for the removal of fluoride dust from floors and equipment, either by wet mopping or a suitable type of vacuum cleaner. Floor drains should be provided at large installations to facilitate the hosing of floors.

3.3.8.6.1. Dry Conveyors

Provision shall be made for the transfer of dry fluoride compounds from shipping containers to storage bins or hoppers to minimize the amount of fluoride dust

3.3.8.6.2. Dust Control Procedures

Plans and specifications for fluoridation equipment and facilities will be reviewed from the standpoint of proposed dust-prevention procedures. Approval will be considered only when they conform to the following:

1. Vacuum pneumatic equipment for drawing powdered material from shipping containers to closed storage hoppers, with the exhaust air from the system effectively filtered and discharged to the exterior.

2. An exhaust fan, with a dust filter and suitable ducts, having capacity to provide a flow of entering air at a velocity of at least 50 m/min at the opening through which the compound is dumped into an otherwise closed hopper or bin from bags, drums or barrels. (The capacity of the fan, therefore, should be selected with due regard to the area of this opening).

3. An enclosure, forming an integral part of the chemical feeder, into which a bag or drum of a fluoride compound may be placed before the container is emptied, so that the emptying process takes place within the enclosure.

4. A drum equipped with a tight-fitting adapter that will allow the drum to be inverted and connected tightly to a mating adapter on top of the hopper, said adapter incorporating a slide gate or other dust-tight means for opening the drum to the hopper after tight connection has been made thereto.

5. A small-capacity dry-feeder fitted with a covered hopper, where only a small quantity of a powdered crystalline or granular form a fluoride compound will be transferred into the hopper at one time, by means of a small hand utensil. (The use of the crystalline or granular form of these compounds is preferred, when so handled).

6. A solution tank containing water, into which a powdered, crystalline, granular, pellet or tablet form of the material is to be placed to form a solution.

7. Any other approved equipment which may be developed for use with a specific type of shipping container or device, which will permit the transfer of the fluoride compound to an enclosed chemical feeder without the release of dust.

3.3.8.6.3. Approval

Complete details of the special provisions for dust prevention shall be included with the submission to the DOEC for the approval of any fluoridation facility.

3.3.8.7. Testing Equipment

Equipment shall be provided for the routine testing of the fluoride ion concentration in the raw and treated water. The equipment shall meet the requirements of the DOEC.

3.3.9. Chemical Application

3.3.9.1. Choice of Chemicals

The choice of chemicals should be determined by on-site or pilot plant tests (e.g. choice of coagulants and coagulant aids). The cost and availability of the chemical should be of prime consideration.

3.3.9.2. Chemical Feed Devices

1. The arrangement of the chemical feed machines and choice of facilities should ensure uniform and continuous treatment.

2. Dry feed, volumetric or gravimetric, or solution feed types are satisfactory and should be provided with a minimum of one standby unit.

3. Feed machines should be equipped with alarm devices to warn operators of failures, and should be capable of ready adjustment to variations in raw water flow.

4. The delivery capacity should be sufficient to supply the required chemical dosage to treat raw water effectively when flowing at the maximum design rate. Devices for recording feed rates are desirable.

5. All feed machines should be located as close as feasible to the point of application of chemicals. Long solution lines or lines encased in floors or walkways should be avoided.

6. It is desirable that chemical solutions, especially suspensions of lime, be conducted in short open flumes. Provision should be made for adequate velocity in the lines to keep the chemical in suspension.

7. Chemical storage rooms should be separate from the feed machine room, and should provide for at least one month's storage of chemicals. Consideration should be given to the dust problem inherent to the application of dry chemicals.

3.3.9.3. Mixing Chamber

1. Retention periods for any type of mixing chamber should be sufficient to ensure thorough mixing, but not long enough to permit formation and settling of the floc.

2. Mechanical mixing devices should be adjustable with respect to mixing rate to account for variations in raw water quality and flow. Mixing devices may be mechanical units, baffled basins, hydraulic jump, aerating devices or other approved types. Selection would depend upon each specific requirement.

3.3.10. Pre-engineered Water Treatment Plants

Pre-engineered water treatment plants are normally modular process units, which are pre-designed for specific process applications and flow rates, and purchased as a package. Multiple units may be installed in parallel to accommodate larger flows.

Pre-engineered treatment plants have numerous applications but are especially applicable for small systems where conventional treatment may not be cost effective. As with any design, the proposed treatment must fit the situation and ensure a continuous supply of safe drinking water for water consumers. The DOEC may accept proposals for pre-engineered water treatment plants on a case by base basis where they have been demonstrated to be effective in treating the source water being used.

Factors to be considered include:

1. Raw water quality characteristics under normal and worst case conditions; seasonal fluctuations must be evaluated and considered in the design;

2. Demonstration of treatment effectiveness under all raw water conditions and systems flow demands; this demonstration may be on-site pilot or full scale testing or testing off-site where the source water is of similar quality. On-site testing is required at sites having questionable water quality or applicability of the treatment process. The proposed demonstration project must be approved by the DOEC prior to commencement;

3. Sophistication of equipment; the reliability and experience record of the proposed treatment equipment and controls must be evaluated;

4. Unit process flexibility which allows for optimization of treatment;

5. Operational oversight that is necessary; at surface water sources, full-time operators are necessary except where the DOEC has approved an automation plan.

6. Third party certification or approval such as National Sanitation Foundation (NSF) for:
   a. Treatment equipment; and

   b. Materials that will be in contact with the water.

7. Suitable pretreatment based on raw water quality and the pilot study or other demonstration of treatment effectiveness;

8. Factory testing of controls and process equipment prior to shipment;

9. Automated troubleshooting capability built into the control system;

10. Start-up and follow-up training and troubleshooting to be provided by the manufacturer or contractor;

11. Operation and maintenance manual; this manual must provide a description of the treatment,

control and pumping equipment, necessary maintenance and schedule, and a troubleshooting guide for typical problems;

12. On-site and contractual laboratory capability; the on-site testing must include all required continuous and daily testing as specified by the DOEC. Contract testing may be considered for other parameters;

13. Manufacturers warranty and replacement guarantee. Appropriate safeguards for the water supplier must be included in contract documents. The DOEC may consider interim or conditional project approvals for innovative technology where there is sufficient demonstration of treatment effectiveness and contract provisions to protect the water supplier should the treatment not perform as claimed; and

14. Water supplier revenue and budget for continuing operations, maintenance and equipment replacement in the future.

3.3.11. Automated/Unattended Operation of Surface Water Treatment Plants

Recent advances in computer technology, equipment controls and SCADA systems have brought automated and off-site operation of surface water treatment plants into the realm of feasibility. Coincidentally, this comes at a time when renewed concern for microbiological contamination is driving optimization of surface water treatment plant facilities and operations and finished water treatment goals are being lowered to levels of <0.1 NTU turbidity and <20 total particle counts per millilitre.

The DOEC encourages any measure, including automation, which assists operators in improving plant operations and surveillance functions.

Automation of surface water treatment facilities to allow unattended operation and off-site control presents a number of management and technological challenges which must be overcome before an Environmental Permit can be considered. Each fact of the plant facilities and operations must be fully evaluated to determine what on-line monitoring is appropriate, what alarm capabilities must be incorporated into the design, and what staffing is necessary. Consideration must be given to the consequences and operational response to treatment challenges, equipment failure and loss of communications or power.

A Technical Report shall be developed as the first step in the process leading to design of the automation system. The Technical Report to be submitted to the DOEC must cover all aspects of the treatment plant and automation system including the following information/criteria:

1. Identify all critical features in the pumping and treatment facilities that will be electronically monitored, have alarms and can be operated automatically or off-site via the control system. Include a description of automatic plant shutdown controls with alarms and conditions, which would trigger shutdowns. Dual or secondary alarms may be necessary for certain critical functions.

2. Automated monitoring of all critical functions with major and minor alarm features must be

provided. Automated plant shutdown is required on all major alarms. Automated start-up of the plant is prohibited after shutdown due to a major alarm. The control system must have response and adjustment capability on all minor alarms. Built-in control system challenge test capability must be provided to verify operational status of major and minor alarms.

3. The plant control system must have the capability for manual operation of all treatment plant equipment and process functions.

4. A plant flow diagram, which shows the location of all, critical features, alarms and automated controls, to be provided.

5. Description of off-site controls station(s) that allow observation of plant operations, receiving alarms and having the ability to adjust and control operation of equipment and the treatment process.

6. An operator shall be on “standby duty” status at all times with remote operational capability and located within a reasonable response time of the treatment plant.

7. An operator shall do an on-site check at least once per day to verify proper operation and plant security.

8. Description of operator staffing and training, planned or completed, in both process control and the automation system.

9. Operations manual, which gives operators step by step procedures for understanding and using the automated control system under all water quality conditions. Emergency operations during power or communications failures or other emergencies must be included.

10. A plan for a 6 month, or more, demonstration period to prove the reliability of procedures, equipment and surveillance system. An operator shall be on-duty during the demonstration period. The final plan must identify and address any problems and alarms that occurred during the demonstration period. Challenge testing of each critical component of the overall system must be included as part of the demonstration project.

11. Schedule for maintenance of equipment and critical parts replacement.

12. Sufficient finished water storage shall be provided to meet system demands and Ct requirements whenever normal treatment production is interrupted as the result of automation system failure or plant shutdown.

13. Sufficient staffing must be provided to carry out daily on-site evaluations, operational functions and needed maintenance and calibration of all critical treatment components and monitoring equipment to ensure reliability of operations.

14. Plant staff must perform, as a minimum, weekly checks on the communication and control system to ensure reliability of operations. Challenge testing of such equipment should be

part of normal maintenance routines.

15. Provisions must be made to ensure security of the treatment facilities at all times. Incorporation of appropriate intrusion alarms must be provided which are effectively communicated to the operator in charge.

3.3.12. Waste Handling and Disposal

Provisions must be made for the proper disposal of water treatment plant waste, such as sanitary, laboratory, clarification sludge, softening sludge, iron sludge, filter backwash water, and brines. All waste discharges shall require the approval of the DOEC as per provisions of the *Environmental Protection Act*. The requirements outlined herein must, therefore, be considered minimum requirements as other regulatory agencies may have more stringent requirements.

In locating waste disposal facilities due consideration should be given to preventing potential contamination of the water supply.

Alternative methods of water treatment and chemical use should be considered as a means of reducing waste handling and disposal problems.

3.3.12.1. Specific Wastes

3.3.12.1.1. Sanitary Waste

The sanitary waste from water treatment plants, pumping stations, and other water works installations must receive treatment. Waste from these facilities must be discharged directly to a sanitary sewer system, or to an adequate on-site waste treatment facility approved by the DOEC.

3.3.12.1.2. Brine Waste

Waste from ion exchange plants, demineralization plants, or other plants, which produce a brine, may be disposed of by controlled discharge to a stream if adequate dilution is available. Surface water quality requirements of the DOEC will control the rate of discharge. Except when discharging to large waterways, a holding tank of sufficient size should be provided to allow the brine to be discharged over a twenty-four hour period. Where discharging to sanitary sewer, a holding tank may be required to prevent overloading of the sewer and/or interference with the waste treatment process. The effect of brine discharge to wastewater treatment ponds may depend on the rate of evaporation from the ponds.

3.3.12.1.3. Sludge

Sludge from plants using lime to soften water varies in quantity and in chemical characteristics depending on the softening process and the chemical characteristics of the water being softened. Recent studies show that the quantity of sludge produced is much larger than indicated by stoic-metric calculations. Methods of treatment and disposal are as follows:

1. Wastewater Treatment Ponds (Lagoons):

a) Temporary wastewater treatment ponds which must be cleaned periodically should be designed on the basis of 2833 m^2 per 3785 m^3 per day per 100 mg/l of hardness removed based on a usable pond depth of 1.5m. This should provide about 2.5 years storage. At least two but preferably more wastewater treatment ponds must be provided in order to give flexibility in operation. An acceptable means of final sludge disposal must be provided. Provisions must be made for convenient cleaning.

b) Permanent wastewater treatment ponds should have a volume of at least four times that for temporary wastewater treatment ponds.

c) The design of both temporary and permanent wastewater treatment ponds should provide for:
   i. Location free from flooding;

   ii. When necessary, dikes, deflecting gutters or other means of diverting surface water so that it does not flow into the wastewater treatment ponds;

   iii. A minimum usable depth of 1.5 m;

   iv. Adequate freeboard of at least 600 mm;

   v. Adjustable decanting device;

   vi. Effluent sampling point;

   vii. Adequate safety provisions; and

   viii. Parallel operation.

2. The application of liquid lime sludge to farmland should be considered as a method of ultimate disposal. Prior to land application, a chemical analysis of the sludge including calcium and heavy metals shall be conducted. Approval from the DOEC and other concerned agencies must be obtained. When this method is selected, the following provisions shall be made:
   a) Transport of sludge by vehicle or pipeline shall incorporate a plan or design which prevents spillage or leakage during transport;

   b) Interim storage areas at the application site shall be kept to a minimum and facilities shall be provided to prevent wash off of sludge or flooding;

   c) Sludge shall not be applied at times when wash off of sludge from the land could be expected;

   d) Sludge shall not be applied to sloping land where wash off could be expected unless provisions are made, for suitable land, to immediately incorporate the sludge into the soil;

e) Trace metals loading shall be limited to prevent significant increases in trace metals in the food chain, phytotoxicity or water pollution; and

f) Each area of land to receive lime sludge shall be considered individually and a determination made as to the amount of sludge needed to raise soil pH to the optimum for the crop to be grown.

3. Discharge of lime sludge to sanitary sewers is not permitted.

4. Mixing of lime sludge with activated sludge waste may be considered as a means of co-disposal.

5. Mechanical dewatering of sludge may be considered. Pilot studies on a particular plant waste are required.

6. Calcination of sludge may be considered. Pilot studies on a particular plant waste are required.

7. Lime sludge drying beds are not recommended.

3.3.12.1.4. Red Water Waste

Waste filter wash water from iron and manganese removal plants can be disposed of as per Section 3.3.12.2.

3.3.12.1.5. Filter Wash Water

Waste filter wash water from surface water treatment or lime softening plants should have suspended solids reduced to a level acceptable to the DOEC before being discharged.

Under special circumstances, a plant may be permitted to construct a holding or sludge concentration tank. The tank should be of such a size that it would contain the anticipated volume of such wastewater produced by the plant when operating at design capacity. A plant that has two filters should have a tank that will contain the total waste wash water from both filters calculated by using a 15-minute wash at 815 L/min/m^2. In plants with more filters, the size of the tank will depend on the anticipated hours of operation.

3.3.12.2. Waste Disposal

3.3.12.2.1. Sand Filters

Sand filters can be used in the disposal of sludge, and should have the following features:

1. Total filter area shall be sufficient to adequately dewater applied solids. Unless the filter is small enough to be cleaned and returned to service in one day, two or more cells are required.

2. The filter shall have sufficient capacity to contain, above the level of the sand, the entire volume of wash water produced by washing all of the production filters in the plant, unless the production filters are washed on a rotating schedule and the flow through the production filters is regulated by the rate of flow controllers. In this case, sufficient volume must be provided to properly dispose of the wash water involved.

3. Sufficient filter surface area should be provided so that, during any one-filtration cycle, no more than 60 cm of backwash water will accumulate over the sand surface.

4. The filter shall not be subject to flooding by surface runoff or floodwaters. Finished grade elevation shall be established to facilitate maintenance, cleaning and removal of surface sand as required. Flashboards or other non-watertight devices shall not be used in the construction of filter sidewalls.

5. The filter media should consist of a minimum of 300 mm of sand, 75 to 100 mm of supporting small gravel or torpedo sand, and 225 mm of gravel in graded layers. All sand and gravel should be washed to remove fines.

6. Filter sand should have an effective size of 0.3 to 0.5 mm and a uniformity coefficient not to exceed 3.5. The use of larger sized sands shall be justified by the designing engineer, to the satisfaction of the DOEC.

7. The filter should be provided with an adequate under-drainage collection system to permit satisfactory discharge of filtrate.

8. Provision shall be made for the sampling of the filter effluent.

9. Overflow devices from the filters shall not be permitted.

10. Where freezing is a problem, provisions should be made for covering the filters during the winter months.

11. Filters shall comply with the common wall provisions contained in Sections 3.6.8.3 and 3.7.7, which pertain to the possibility of contaminating treated water with unsafe water. The DOEC must be contacted for approval of any arrangement where a separate structure is not provided.

3.3.12.2.2. Wastewater Treatment Ponds (Lagoons)

Wastewater treatment ponds shall have the following features:

1. Be designed with volume 10 times the total quantity of wash water discharged during any 24-hour period;

2. A minimum usable depth of 900 mm;

3. Length four times width, and the width at least three times the depth, as measured at the operating water level;

4. Outlet to be at the end opposite the inlet;

5. A weir overflow device at the outlet end with weir length equal to or greater than depth; and

6. Velocity to be dissipated at the inlet end.

3.3.12.2.3. Recycling Waste Filtrates
Recycling of supernatant or filtrate from waste treatment facilities to the head end of the plant shall not be allowed except as approved by the DOEC.

3.4. Chemical Application

Chemicals shall be applied to the water at such points and by such means as to:
1. Assure maximum efficiency of treatment;

2. Assure maximum safety to the consumer;

3. Provide maximum safety to the operators;

4. Assure satisfactory mixing of the chemicals with the water;

5. Provided maximum flexibility of operation through various points of application, when appropriate; and

6. Prevent backflow or back-siphonage between multiple points of feed through common manifolds.

3.4.1. Approval

No chemicals shall be applied to treat drinking waters unless specifically permitted by the DOEC.

Plans and specifications shall be submitted for review and approval, as provided for in Section 2, and shall include:
1. Descriptions of feed equipment, including maximum and minimum feed ranges;

2. Location of feeders, piping layout and points of application;

3. Storage and handling facilities;

4. Specifications for chemicals to be used;

5. Operating and control procedures including proposed application rates; and

6. Descriptions of testing equipment and procedures.

3.4.2. General Equipment Design

General equipment design shall be such that:

1. Feeders will be able to supply, at all times, the necessary amounts of chemicals at an accurate rate, throughout the range of feed;

2. Chemical-contact materials and surfaces are resistant to the aggressiveness of the chemical solution;

3. Corrosive chemicals are introduced in such a manner as to minimize potential for corrosion;

4. Chemicals that are incompatible are not stored or handled together;

5. All chemicals are conducted from the feeder to the point of application in separate conduits;

6. Chemical feeders are as near as practical to the feed point;

7. Chemical feeders and pumps should operate as per the manufacturer's recommendations; and

8. Chemicals are fed by gravity where practical.

3.4.3. Facility Design

3.4.3.1 Number of Feeders

1. Where chemical feed is necessary for the protection of the supply, such as chlorination, coagulation or other essential processes:
   a) A minimum of two feeders shall be provided;

   b) The standby unit or a combination of units of sufficient capacity should be available to replace the largest unit during shut-downs; and

   c) Where a booster pump is required, duplicate equipment shall be provided and, when necessary, standby power.

2. A separate feeder shall be used for each chemical applied.

3. Spare parts shall be available for all feeders to replace parts, which are subject to wear and damage.

3.4.3.2. Control of Facility

1. Feeders may be manually or automatically controlled, with automatic controls being designed so as to allow override by manual controls.

2. At automatically operated facilities, chemical feeders shall be electrically interconnected with the well or service pump and should be provided a non-standard electrical receptacle.

3. Chemical feed rates shall be proportional to flow.

4. A means to measure water flow must be provided in order to determine chemical feed rates.
5. Provisions shall be made for measuring the quantities of chemicals used.

6. Weighing scales:
    a) Shall be provided for weighing cylinders at all plants utilizing chlorine gas;

    b) May be required for fluoride solution feed;

    c) Should be provided for volumetric dry chemical feeders; and

    d) Shall be capable of providing reasonable precision in relation to average daily dose.

7. Where conditions warrant, for example with rapidly fluctuating intake turbidity, coagulant and coagulant aid addition may be made according to turbidity, streaming current or other sensed parameter.

3.4.3.3. Dry Chemical Feeders

Dry chemical feeders shall:
1. Measure chemicals volumetrically or gravimetrically;

2. Provide adequate solution water and agitation of the chemical in the solution tank;

3. Provide gravity feed from solution pots; and

4. Completely enclose chemicals to prevent emission of dust to the operating room.

3.4.3.4. Positive Displacement Solution Pumps

Positive displacement type solution feed pumps should be used to feed liquid chemicals, but shall not be used to feed chemical slurries. Pumps must be capable of operating at the required maximum rate against the maximum head conditions found at the point of injection.

3.4.3.5. Liquid Chemical Feeders – Siphon Control

Liquid chemical feeders shall be such that chemical solutions cannot be siphoned into the water supply, by:
1. Assuring discharge at a point of positive pressure;

2. Providing vacuum relief;

3. Providing a suitable air gap; or

4. Providing other suitable means or combinations as necessary.

3.4.3.6. Cross-connection Control

Cross-connection control must be provided to assure that:

1. The service water lines discharging to solution tanks shall be properly protected from backflow as required by the DOEC (see Section 4.2.5.7);

2. Liquid chemical solutions cannot be siphoned through solution feeders into the water supply as required in Section 3.4.3.5; and

3. No direct connection exists between any sewer and a drain or overflow from the feeder, solution chamber or tank by providing that all drains terminate at least 150 mm or two pipe diameters, whichever is greater, above the overflow rim of a receiving sump, conduit or waste receptacle.

3.4.3.7. Chemical Feed Equipment Location

Chemical feed equipment shall be:

1. Readily accessible for servicing, repair, and observation of operation;

2. Located in a separate room where required to reduce hazards and dust problems;

3. Conveniently located near points of application to minimize length of feed lines; and

4. Located such that the flow to the rapid mix is by gravity.

3.4.3.8. In-plant Water Supply

In-plant water supply shall be:

1. Ample in quantity and adequate in pressure;

2. Provided with means for measurement when preparing specific solution concentrations by dilution;

3. Properly treated for hardness, when necessary;

4. Properly protected against backflow, and

5. Obtained from a location sufficiently downstream of any chemical feed point to assure adequate mixing.

3.4.3.9. Storage of Chemicals

1. Space should be provided for:
   a) At least 30 days of chemical supply;

   b) Convenient and efficient handling of chemicals;

   c) Dry storage conditions; and

d) A minimum storage volume of 1½ truck loads where purchase is by truckload lots.

2. Storage tanks and pipelines for liquid chemicals shall be specified for use with individual chemicals and not used for different chemicals.

3. Chemicals shall be stored in covered or unopened shipping containers, unless the chemical is transferred into an approved storage unit.

4. Liquid chemical storage tanks must:

    a) Have a liquid level indicator; and

    b) Have an overflow and a receiving basin capable of receiving accidental spill or overflows without uncontrolled discharge.

3.4.3.10. Solution Tanks

1. A means, which is consistent with the nature of the chemical solution, shall be provided in a solution tank to maintain a uniform strength of solution. Continuous agitation shall be provided to maintain slurries in suspension.

2. Two solution tanks of adequate volume may be required for a chemical to assure continuity of supply while servicing a solution tank.

3. Means shall be provided to measure the liquid level in the tank.

4. Chemical solutions shall be kept covered. Large tanks with access openings shall have such openings curbed and fitted with overhanging covers.

5. Subsurface locations for solution tanks shall:
    a) Be free from sources of possible contamination; and

    b) Assure positive drainage for groundwater, accumulated water, chemical spills and overflows

6. Overflow pipes, when provided, should:
    a) Be turned downward, with the end screened;

    b) Have a free fall discharge; and

    c) Be located where noticeable.

7. Acid storage tanks must be vented to the outside atmosphere, but not through vents in common with day tanks.

8. Each tank shall be provided with a valved drain, protected against backflow in accordance with Sections 3.4.3.5 and 3.4.3.6.

9. Solution tanks shall be located and protective curbings provided so that chemicals from equipment failure, spillage or accidental drainage shall not enter the water in conduits, treatment or storage basins.

3.4.3.11. Day tanks

1. Day tanks shall be provided where bulk storage of liquid chemical is provided.

2. Day tanks shall meet all the requirements of Section 3.4.3.10.

3. Day tanks should hold no more than a 30-hour supply.

4. Day tanks shall be scale-mounted, or have a calibrated gauge painted or mounted on the side if liquid level can be observed in a gauge tube or through translucent sidewalls of the tank. In opaque tanks, a gauge rod extending above a reference point at the top of the tank, attached to a float may be used. The ratio of the area of the tank to its height must be such that unit readings are meaningful in relation to the total amount of chemical fed during a day.

5. Hand pumps may be provided for transfer from a carboy or drum. A tip rack may be used to permit withdrawal into a bucket from a spigot. Where motor-driven transfer pumps are provided, a liquid level limit switch and an over-flow from the day tank, must be provided.

6. A means, which is consistent with the nature of the chemical solution, shall be provided to maintain uniform strength of solution in a day tank. Continuous agitation shall be provided to maintain chemical slurries in suspension.

7. Tanks and tank refilling line entry points shall be clearly labelled with the name of the chemical contained.

3.4.3.12. Feed Lines

1. Should be as short as possible, and:
   a) Be of durable, corrosion-resistant material;

   b) Easily accessible throughout the entire length;

   c) Protected against freezing; and

   d) Readily cleanable.

2. Should slope upward from the chemical source to the feeder when conveying gases;

3. Shall be designed consistent with scale-forming or solids depositing properties of the water, chemical, solution or mixtures conveyed; and

4. Should be colour-coded.

3.4.3.13. Handling

1. Carts, elevators and other appropriate means shall be provided for lifting chemical containers to minimize excessive lifting by operators.

2. Provisions shall be made for disposing of empty bags, drums or barrels by an approved procedure, which will minimize exposure to dusts.

3. Provision must be made for the proper transfer of dry chemicals from shipping containers to storage bins or hoppers, in such a way as to minimize the quantity of dust, which may enter the room in which the equipment is installed. Control should be provided by use of:
   a) Vacuum pneumatic equipment or closed conveyor systems;

   b) Facilities for emptying shipping containers in special enclosures; and/or

   c) Exhaust fans and dust filters, which put the hoppers or bins under negative pressure.

4. Provision shall be made for measuring quantities of chemicals used to prepare feed solutions.

3.4.3.14. Housing

1. Floor surfaces shall be smooth and impervious, slip-proof and well drained with 2.5 %, minimum slope.

2. Vents from feeders, storage facilities and equipment exhaust shall discharge to the outside atmosphere above grade and remote from air intakes or exit doors.

3.4.4. Chemicals

3.4.4.1. Shipping Containers

Chemical shipping containers shall be fully labelled to include:
1. Chemical name, purity and concentration; and

2. Supplier name and address.

3.4.4.2. Specifications

Chemicals and water contact materials shall meet ANSI/AWWA quality standards and ANSI/NSF Standard 60 or 61 safety standards.

3.4.4.3. Assay

Provisions may be required for assay of chemicals delivered.

3.4.5. Operator Safety

3.4.5.1. Ventilation

Special provisions shall be made for ventilation of chemical feeder and storage rooms.

3.4.5.2. Protective Equipment

1. At least one pair of rubber gloves, a dust respirator of a type certified by Occupational Health and Safety for toxic dusts, an apron or other protective clothing and goggles or face mask shall be provided for each operator as required by the DOEC. A deluge shower and/or eye-washing device should be installed where strong acids and alkalis are used or stored.

2. A water holding tank that will allow water to come to room temperature must be installed in the water line feeding the deluge shower and eye-washing device. Other methods of water tempering will be considered on an individual basis.

3. Other protective equipment should be provided as necessary.

3.4.6. Specific Chemicals

3.4.6.1. Acids and Caustics

1. Acids and caustics shall be kept in closed corrosion-resistant shipping containers or storage units.

2. Acids and caustics shall not be handled in open vessels, but should be pumped in undiluted form from original containers through suitable hose, to the point of treatment or to a covered day tank.

3.4.6.2. Sodium Chlorite for Chlorine Dioxide Generation

Proposals for the storage and use of sodium chlorite must be approved by the DOEC prior to the preparation of final plans and specifications. Provisions shall be made for proper storage and handling of sodium chlorite to eliminate any danger of fire or explosion associated with its powerful oxidizing nature.

1. **Storage:**
   a) Chlorite (sodium chlorite) shall be stored by itself in a separate room and preferably shall be stored in an outside building detached from the water treatment facility. It must be stored away from organic materials because many materials will catch fire and burn violently when in contact with chlorite.

   b) The storage structures shall be constructed of non-combustible materials.

   c) If the storage structure must be located in an area where a fire may occur, water must be available to keep the sodium chlorite area cool enough to prevent heat induced explosive decomposition of the chlorite.

2. **Handling:**

a) Care should be taken to prevent spillage.

b) An emergency plan of operation should be available for the cleanup of any spillage.

c) Storage drums must be thoroughly flushed prior to recycling or disposal.

3. Feeders:

a) Positive displacement feeders shall be provided.

b) Piping for conveying sodium chlorite or chlorine dioxide solutions shall be Type 1 PVC, polyethylene or materials recommended by the manufacturer.

c) Chemical feeders may be installed in chlorine rooms if sufficient space is provided or facilities meeting the requirements of subsection 3.4.1 shall be provided.

d) Feed lines shall be installed in a manner to prevent formation of gas pockets and shall terminate at a point of positive pressure.

e) Check valves shall be provided to prevent the backflow of chlorine into the sodium chlorite line.

3.5. Pumping Facilities

Pumping facilities shall be designed to maintain the sanitary quality of pumped water. Subsurface pits or pump rooms and inaccessible installations should be avoided. No pumping stations should be subject to flooding.

Where raw water is drawn from surface water (streams, lakes, reservoirs, etc.) the design of the intake conduit, and suction wall should receive special attention to prevent clogging caused by trash, silt settling, or ice formation.

3.5.1. Location

The pumping station shall be so located that the proposed site will meet the requirements for sanitary protection of water quality, hydraulics of the system and protection against interruption of service by fire, flood or any other hazard.

The station shall be:

1. Elevated to a minimum of 0.9 m above the 100 year flood elevation, or 0.9 m above the highest recorded flood elevation, whichever is higher, or protected to such elevations;

2. Readily accessible at all times unless permitted to be out of service for the period of inaccessibility;

3. Graded around the station so as to lead surface drainage away from the station; and

4. Protected to prevent vandalism and entrance by unauthorized persons or animals.

3.5.2. Pumping Stations

Both raw and finished water-pumping stations shall:

1. Have adequate space for the installation of additional units if needed, and for the safe servicing of all equipment;

2. Be of durable construction, fire and weather resistant and with outward-opening doors;

3. Have floor elevation of at least 150 mm above finished grade, and the underground structure waterproofed;

4. Have all floors drained in such a manner that the quality of the potable water will not be endangered. All floors should have a slope of at least 2.5% to a suitable drain; and

5. Provide a suitable outlet for drainage from pump glands without discharging onto the floor.

3.5.2.1. Suction Well

Suction wells shall:

1. Be watertight;

2. Have floors sloped to permit removal of water and entrained solids;

3. Be covered or otherwise protected against contamination; and

4. Have two pumping compartments or other means to allow the suction well to be taken out of service for inspection, maintenance or repair.

3.5.2.2. Equipment Servicing

Pump stations should be provided with:

1. Crane-ways, hoist beams, eyebolts, or other adequate facilities for servicing or removal of pumps, motors or other heavy equipment;

2. Openings in floors, roofs or wherever else needed for removal of heavy or bulky equipment; and

3. A convenient tool board, or other facilities as needed, for proper maintenance of the equipment.

3.5.2.3. Stairways and Ladders

Stairs are preferred in areas were there is frequent traffic or where supplies are transported by hand. They shall meet the requirements of the Department of Government Services, Occupational Health and Safety Division.

Stairways or ladders shall:

1. Be provided between all floors, and in pits or compartments which must be entered; and

2. Have handrails on both sides, and treads of non-slip material.

3.5.2.4. Heating

Provisions should be made for adequate heating for:

1. The comfort of the operator; and

2. The safe and efficient operation of the equipment.

In pump houses not occupied by personnel, only enough heat need be provided to prevent freezing of equipment or treatment process.

3.5.2.5. Ventilation

Ventilation should conform to existing local and/or provincial codes. Adequate ventilation should be provided for all pumping stations. Forced ventilation of at least six changes of air per hour shall be provided for:

1. All confined rooms, compartments, pits and other enclosures below ground floor; and

2. Any area where unsafe atmosphere may develop or where excessive heat may be built up.

3.5.2.6. Dehumidification

In areas where excess moisture could cause hazards to safety or damage to equipment, means for dehumidification should be provided.

3.5.2.7. Lighting

Pump stations should be adequately lighted throughout. All electrical work shall conform to the requirements of the Canadian Electrical Code and related agencies and to the relevant Provincial codes.

3.5.2.8. Sanitary and Other Conveniences

Except in the cases of small automatic stations or where such facilities are otherwise available, all pumping stations should be provided with potable water, lavatory and toilet facilities. Plumbing must be so installed as to prevent contamination of a public water supply. Wastes should be discharged to a disposal system approved by the DOEC.

3.5.3. Pumps

At least two pumping units should be provided. With any pump out of service, the remaining pump or pumps shall be capable of providing the maximum daily pumping demand of the system. The pumping units shall:

1. Have ample capacity to supply the peak demand against the required distribution system pressure without dangerous overloading;

2. Be driven by ~~a~~ prime movers able to meet the maximum horsepower condition of the pumps;

3. Have spare parts and tools readily available; and

4. Be served by control equipment that has proper heater and overload protection for air temperature encountered.

3.5.3.1. Suction Lift

Suction lift shall be:

1. Avoided, if possible, and

2. Within allowable limits, preferably less than 4.5 m.

Where suction lift is necessary, self-priming pumps shall be provided.

3.5.3.2. Priming

Prime water must not be of lesser sanitary quality than that of the water being pumped. Means should be provided to prevent backpressure or back-siphonage backflow. When an air-operated ejector is used, the screened intake shall draw clean air from a point at least 3 m above the ground or other source of possible contamination, unless the air is filtered by an apparatus approved by the DOEC. Vacuum priming may be used.

3.5.4. Booster Pumps

Booster pumps shall be located or controlled so that:

1. They will not produce negative pressure in their suction lines;

2. The intake pressure should be at least 140 kPa when the pump is in normal operation;

3. The automatic cut-off or low pressure controller shall maintain at least 70 kPa in the suction line under all operating conditions;

4. Automatic or remote control devices shall have a range between the start and cut-off pressure which will prevent excessive cycling; and

5. A bypass is available.

3.5.4.1. Duplicate Pumps

Each booster pumping station should contain not less than two pumps with capacities such that peak demand can be satisfied with the largest pump out of service.

3.5.4.2. Metering

All booster-pumping stations should contain a totalizer meter.

3.5.4.3. Inline Booster Pumps

In addition to the other requirements of this section, inline booster pumps should be accessible for servicing and repairs.

3.5.4.4. Individual Home Booster Pumps

Individual home booster pumps should not be considered or required for any individual service from the public water supply main.

3.5.5. Automatic and Remote Controlled Pumping Stations

All automatic pumping stations shall be provided with automatic signalling apparatus, which will report when the station is out of service. All remote controlled stations shall be electrically operated and controlled and have signalling apparatus of proven performance. Installation of electrical equipment shall conform to the applicable Canadian and Provincial electrical codes.

3.5.6. Appurtenances

3.5.6.1. Valves

Pumps shall be adequately valved to permit satisfactory operation, maintenance and repair of the equipment. If foot valves are necessary, they should have a net valve area of at least 2.5 times the area of the suction pipe and they should be screened. Each pump shall have a positive-acting check valve on the discharge side between the pump and the shut-off valve. When the pumps are operating with positive suction pressure shut off valves should be also located in the suction lines.

3.5.6.2. Piping

In general piping shall:

1. Be designed so that the friction losses will be minimized;
2. Not be subject to contamination;
3. Have watertight joints;
4. Be protected against surge or water hammer and provided with suitable restraints where necessary; and
5. Be such that each pump has an individual suction line or that the lines shall be so manifolded that they will insure similar hydraulic and operating conditions.

3.5.6.3. Gauges and Meters

Each pump shall have:

1. A standard pressure gauge on its discharge line;
2. A compound gauge on its suction line;

3. Recording gauges in the larger stations; and

4. A means for measuring the discharge.

The station should have indicating, totalizing, and recording metering of the total water pumped.

3.5.6.4. Water Seals

Water seals shall not be supplied with water of a lesser sanitary quality than that of the water being pumped. Where pumps are sealed with potable water and are pumping water of lesser sanitary quality the seal shall:

1. Be provided with either an approved reduced pressure principle backflow preventer or a break tank open to atmospheric pressure,

2. Where a break tank is provided, have an air gap of at least 150 mm or two times the pipe diameter, whichever is greater, between the feed line and the flood rim of the tank.

3.5.6.5. Controls

Pumps, their prime movers and accessories, shall be controlled in such a manner that they will operate at rated capacity without dangerous overload. Where two or more pumps are installed, provision should be made for alternation. Provision shall be made to prevent energizing the motor in the event of a backspin cycle. Electrical controls should be located above grade. Equipment shall be provided or other arrangements made to prevent surge pressures from activating controls, which switch on pumps or activate other equipment outside the normal design cycle of operation.

3.5.6.6. Standby Power

To ensure continuous service when the primary power has been interrupted, a power supply shall be provided from an auxiliary source. If onsite generators or engines provide standby power, the fuel storage and fuel line must be designed to protect the water supply from contamination, and shall be in compliance with the *Storage and Handling of Gasoline and Associated Products Regulations, 2003*. As well, approval from the Department of Government Services will be required.

3.5.6.7. Water Pre-lubrication

When automatic pre-lubrication of pump bearings is necessary and an auxiliary direct drive power supply is provided, the pre-lubrication line should be provided with a valved bypass around the automatic control so that the bearings can, if necessary, be lubricated manually before the pump is started or the pre-lubrication controls shall be wired to the auxiliary power supply.

3.6. Finished Water Storage

Water storage is essential for meeting all of the domestic, public, industrial, commercial and fire-flow demands of almost all public water systems. This section addresses the requirements of treated water storage.

3.6.1. Definitions

Age of Treated Water – The age of treated water is measured as the time from when disinfection took place.

Detention Time – Detention time (sometime known as retention time or residence time) is defined as the period during which the treated water remains in storage prior to entering the distribution system. This may not be a fixed period and is dependent on utilization of the treated water and mixing of the treated water in storage. There could also be significant detention time within the distribution system prior to water reaching the first customer.

Elevated Tank – Elevated Tanks generally consist of a water tank supported by a steel or concrete tower that does not form part of the storage volume. In general, an elevated tank supplies peak balancing flows. See Figure 3.1a.

Standpipe – A standpipe is a tank that is located on the ground surface and has a greater height than diameter. In most installations water in the upper portion of the tank is used for peak flow balancing (equalization), the remaining volume is for fire flow and emergency storage. See Figure 3.1b.

Reservoir – A treated water reservoir is a storage facility where the width/diameter is typically greater than the height and usually applies to large storage facilities.

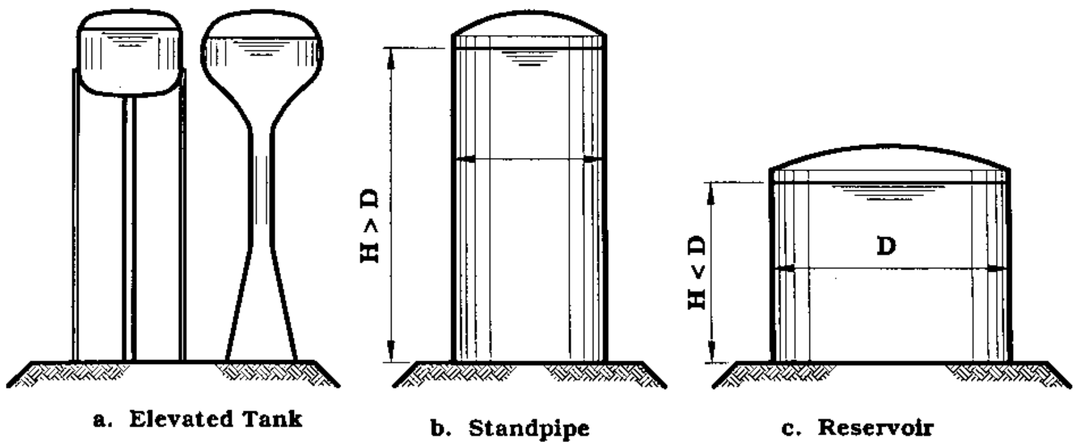
Above Ground Reservoir – An above ground reservoir is a water storage structure that is primarily above ground. See Figure 3.1c.

In-Ground Reservoir – An in-ground reservoir is a water storage structure that is partially below the nominal surface of the ground. A typical construction has the reservoir located 50% above and 50% below ground.

3.6.2. Hydropneumatic Systems

Hydropneumatic tanks are partly filled with water and partly filled with air. They are generally steel pressure tanks, with a flexible membrane that separates the air and the water. Air is compressed in the upper part of the tank and is used to maintain water pressure in the distribution system when demand exceeds the pump capacity. It also reduces on-off cycling of pumps.

Figure 3.1
Above Ground Storage



3.6.3. Materials of Construction

3.6.3.1. Standards and Materials Selection

Storage facilities, including pipes, fittings and valves, should conform to the latest standards issued by the CSA or AWWA, and be acceptable to the DOEC. In the absence of such standards, materials meeting applicable Product Standards and acceptable to the DOEC may be selected. Special attention should be given to selecting pipe materials that will protect against internal and external pipe corrosion. All products should comply with CSA/ANSI standards. Any material that comes in contact with drinking water must comply with NSF Standard 61.

Other materials of construction are acceptable when properly designed to meet the requirements of treated water storage including concrete.

3.6.3.2. Steel Construction

Steel structures should follow the current AWWA standards concerning steel tanks, standpipes, reservoirs, and elevated tanks wherever they are applicable. Painted welded steel and pre-finished bolted steel tanks are options for treated water storage tanks.

3.6.3.3. Concrete Construction

Concrete structures should follow the current AWWA standards concerning concrete tanks, standpipes, reservoirs, and elevated tanks wherever they are applicable.

3.6.4. Design Criteria

The top water level and location of the storage structures will be determined by the hydraulic analysis undertaken for the design of the distribution system to result in acceptable service pressures throughout the existing and future service areas.

The materials and design used for treated water storage structures should provide stability and durability as well as protect the quality of the stored water. The following subsections outline criteria that should be considered when designing treated water storage facilities.

3.6.4.1. Demand Equalization (Peak Balancing Storage)

The demand for water normally changes throughout the day and night. If treated water is not available from storage, the wells and/or treatment plant must have sufficient capacity to meet the demand at peak flow. The capacity is not generally practical or economical. With adequate storage, water can be treated or supplied to the system at a relatively uniform rate over a 24-hour period with peak balancing flows at high demand periods during the day being supplied by water storage tanks.

3.6.4.2. System Operation (Convenience)

In some situations, storage is provided to allow a treatment plant to be operated for only one or two shifts, thereby reducing personnel costs. In this situation storage provides the water required for the periods of time when the plant shuts down.

3.6.4.3. Smoothing Pumping Requirements

The demand for water is continually changing in all water systems, depending on time of day, day of the week, weather conditions and many other factors. If there is no storage at all, the utility has to continually match the changing demand by selecting pumps of varying sizes. Frequent cycling of pumps causes increased wear on controls and motors. It also increases energy costs. Adequate elevated storage can minimize this effect by providing peak flow balancing capacity.

3.6.4.4. Reducing Power Costs

Storage allows for pumping costs to be reduced, by reducing start-ups, avoiding using large pumps at peak demands and also benefiting from off-peak rates offered by the electricity utility during the night.

3.6.4.5. Emergency Storage

During periods of power failure, mechanical or pipeline breakdown or maintenance when use of source water is prevented, there is a need for emergency storage.

3.6.4.6. Fire Storage

Fire demands may not occur very often, however, when it does occur, the rate of water use is usually much greater than for domestic peak demand. Also, the required fire storage volume can account for as much as 50% of total capacity of the reservoirs.

3.6.4.7. Pressure Surge Relief

When pumps are turned on and off and when valves are opened and closed, large pressure changes can occur throughout the distribution system, which can damage pipes and appurtenances. Water storage tanks provide some assistance in absorbing pressure surges.

3.6.4.8. Detention Time

The time that water stays in storage after disinfectants are added, but before the water is delivered to the first customer, can be counted towards the disinfectant contact time.

Supplemental chlorination may be required to maintain minimum chlorine residuals in water from water storage facilities that has insufficient residual chlorine.

A detailed design of the inlet, outlet and baffling is required where storage facilities are used as supplemental chlorination stations.

3.6.4.9. Blending of Water Sources

Some water systems use water from two or more sources, with each source having different water quality. The feasibility of the blending of sources should be investigated, as the chemical quality of blended water may affect the integrity of the distribution system.

3.6.5. Sizing of Water Storage Facilities

Storage facilities should have sufficient capacity, as determined from engineering studies, to meet the required domestic demands, and where fire protection is provided, fire flow demands. Emergency storage volumes should be provided to supply demands in the event of pipeline or equipment breakdowns or maintenance shutdowns. Excessive storage capacity should be avoided where water quality deterioration may occur.

The total water storage requirements for a given water supply system where the treatment plant is capable of satisfying only the maximum day demand may be calculated using the following equation:

$$S = A + B + C$$

Where: S = Total Storage requirement, m^3;
A = Fire Storage, m^3 (equal to required fire flow over required duration);
B = Peak Balanced Storage, m^3 (25% of maximum day demand); and
C = Emergency Storage, m^3 (25% of A + B).

Notes:
1. The above equation is for the calculation of the storage requirement for a system where the water treatment plant is capable of satisfying only the maximum day demand. For situations where the water treatment plant can supply more, the above storage requirements can be reduced accordingly.
2. The maximum day demand referred to in the foregoing equation should be calculated using the factors in Table 3.7, unless there is existing flow data available to support the use of different factors. Where existing data is available, the required storage should be calculated on the basis of an evaluation of the flow characteristics within the system.

3. Should the proponent have decided to provide a potable water supply and distribution system not capable of providing fire protection, the usable volume of storage to be provided should be 25% of design year maximum day plus 40% of the design year average day.

4. The designer should recognize that this formula for calculating treated water storage requirements must be supplemental with the plant water storage required for the operation of the water treatment facility (i.e. backwash and domestic use).

3.6.5.1. Fire Flow Storage Requirements

The level of fire protection is the responsibility of the municipality. Fire flow requirements, typically established by the appropriate Insurance Advisory Organization (IAO), should be satisfied where fire protection is provided. The level of storage may be further reduced if the water treatment plant is capable of supplying portions of the required fire-flow volumes.

3.6.5.2. Peak Balancing Storage Requirements

Peak balancing storage also known as operational storage is directly related to the amount of water necessary to meet peak demands. The intent of peak balancing storage is to make up the difference between the consumer's peak demands and the system's available supply. With peak balancing storage, system pressures are typically improved and stabilized. The value of the peak balancing storage is a function of the diurnal demand fluctuation in a community and is commonly estimated at 25% of the total maximum day demand.

3.6.5.3. Emergency Storage

This is the volume of water recommended to meet the demand during maintenance shut-downs or emergency situations, such as source of supply failures, watermain failures, electrical power outages, or natural disasters. The amount of emergency storage included with a particular water system is not set, but is typically based on an assessment of risk and desired degree of system dependability.

In considering emergency storage, it is acceptable to evaluate providing significantly reduced supplies during emergencies.

In the absence of clear information, 15% of projected average daily design flow can be used, or 25% of (Peak Balancing + Fire Flow).

3.6.5.4. Dead Storage

If a storage structure is of a type where only the upper portion of the water provides a useful function, such as maintaining usable system pressure, the remaining lower portion is considered dead storage. Dead storage can be considered useful if pumps can withdraw the water from the lower portion of the storage structure during a fire or other emergency. Where dead storage is present there must be adequate measures taken to circulate the water through the tank to maintain quality and prevent freezing (i.e. baffles, loading/unloading techniques, and adequate mixing provisions). Unusable dead storage should be avoided wherever possible.

3.6.5.5. Turnover and Water Quality

Deterioration in water quality is frequently associated with the age of the water. Loss of disinfection residual, formation of DBPs, and bacterial re-growth can all result from aging of water. As a result, an implicit objective in both design and operation of distribution system storage facilities is the minimization of detention time and the avoidance of volumes of water that remain in the storage facility for long periods. The allowable detention time should depend on the quality of the water, its reactivity, the type of disinfectant used and the travel time before and after the water's entry into the storage facility. A maximum 72-hour turnover is a reasonable guideline. If it is not possible to have sufficient turnover of water in the storage facility, supplemental disinfection may be required.

In cases where taste and odour problems exist and/or where excessive levels of DBPs are generated, bleeding at the ends of the system is a recommended measure provided that the chlorine levels are neutralized prior to discharge to receiving waters.

3.6.5.6. Plant Storage

The designer should recognize the need to calculate, in addition to distribution storage requirements, the requirement for the operation of the water treatment facility (i.e. backwash and domestic use).

3.6.5.6.1. Clearwell Storage

Clearwell storage should be sized, in conjunction with distribution system storage, to avoid frequent on/off cycling of the treated water pumps. A minimum of two compartments along with adequate measures for circulation should be provided. Clearwells that can be depleted should not be used to achieve the required chlorine contact times. A separate contact tank should be provided to meet the disinfection requirements.

3.6.6. Location of Distribution Storage

The location of distribution storage is closely associated with the system hydraulics and water demands in various parts of the system. Location of the storage facilities at natural high points within the area being serviced by the water system allows for gravitational advantage and potential considerable cost savings. The site selection process is often also affected by the availability of appropriate land and public acceptance of the structure.

3.6.6.1. Elevated Storage

Elevated Storage includes elevated tanks and the upper portion of water stored within standpipes. Elevated storage facilities that have existed for several years rarely bother the public, however, property owners will often object to a new one being built near their homes. Designs can be very pleasing and landscaping and colours can be used to minimize or even enhance the visual effect. This may not however be enough to overcome the objections of the local community and it may be necessary to build water elevated storage facilities at non-ideal locations from both topographic and hydraulic perspectives. Industrial zones may provide some opportunities, otherwise alternative facilities using above ground and in-ground water storage and pumps may be required.

3.6.6.2. Above Ground and In-Ground Storage Reservoirs

Low level above ground and in-ground storage reservoirs are generally used where a large quantity of water must be stored. A relatively large parcel of land is required to accommodate both the reservoir and the accompanying pump station.

The following are considered minimum requirements:

1. The bottom of above ground reservoirs and standpipes should be placed at the normal ground surface and should be above maximum flood level based on a 100-year flood;

2. When the bottom of the storage reservoir must be below normal ground surface, the in-ground reservoir should be placed above the groundwater table. Typically at least 50% of the water depth should be above grade. Sewers, drains, standing water, and similar sources of possible contamination must be kept at least 15 m from the reservoir; and

3. The top of an in-ground reservoir should not be less than 600 mm above normal ground surface. Clearwells constructed under filters may be exempted from this requirement when the total design gives the same protections.

3.6.7. Facility Requirements

3.6.7.1. Inlet/Outlet and Baffle Wall

A detailed design of the inlet, and outlet and, if required, baffle walls, mixing, etc., is required to ensure maximum turnover of water in a storage tank.

3.6.7.2. Level Control

Adequate controls should be provided to maintain levels in distribution system storage structures. Level indicating devices should be provided at a central location. Key issues are:

1. Pumps should be controlled from tank levels with the signal transmitted by telemetry equipment when any appreciable head loss occurs in the distribution system between the source and the storage structures;

2. Altitude valves or equipment controls are required to control pump on-off cycles or gravity flow to and from the tank to maintain the system pressures and avoid overflows;

3. Overflow and low-level warnings or alarms should be located at places in the community where they will be under responsible surveillance 24 hours a day; and

4. Changes in water level in a storage tank during daily domestic water demands should be limited to a maximum 9 m to stabilize pressure fluctuations within the distribution system.

3.6.7.3. Overflow

All above ground water storage structures should be provided with an overflow, which is brought to an elevation between 300 mm and 600 mm above the ground surface, and discharges over a drainage inlet structure or a splash plate. An overflow shall not be connected directly to a sewer or storm drain. All overflow pipes should be located so that any discharge is visible.

When an internal overflow pipe is used on elevation tanks, it should be located in the access tube. For vertical drops on other types of storage facilities, the overflow pipe should be located on the outside of the structure.

The overflow of a ground-level structure should open downward and be screened with 24-mesh non-corrodible screen installed within the pipe at a location least susceptible to damage by vandalism. Overflows should be located at sufficient elevation to prevent the entrance of surface water. A backflow preventer should be installed on all overflows, on in-ground or low-elevation reservoirs.

The overflow pipe should be of sufficient diameter to permit the wasting of water in excess of the filling rate.

Consideration should be given to downgrade receiving areas of overflow water. Adequate surface detention should be provided to prevent soil erosion and to provide safe dissipation of chlorine.

The discharge must not be directed to natural water bodies. Discharge in residential areas should be contained to appropriate and controlled storm water channels.

3.6.7.4. Drainage of Storage Structures

Water storage structures, which provide pressure directly to the distribution system, should be designed so they can be isolated from the distribution system and drained for cleaning or maintenance without necessitating loss of pressure in the distribution system. The drain should discharge to the ground surface with no direct connection to a sewer or municipal storm drain, and should be located at least 300 mm above ground surface.

Water that is drained from storage structures should be dechlorinated prior to discharge to the environment.

3.6.7.5. Roof Drainage

The roof of the storage structure should be well drained. Downspout pipes should 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.

3.6.7.6. Roof and Sidewall

The roof and sidewall of all structures must be watertight with no opening except properly constructed vents, manholes, overflows, risers, drains, pump mountings, control ports, or piping for inflow and outflow.

1. Any pipes running through the roof or sidewall of a treated water storage structure must be welded, or properly gasketed in metal tanks. In concrete tanks, these pipes should be connected to standard wall castings, which were poured in place during the forming of the concrete. These wall castings should have seepage rings imbedded in the concrete;

2. Openings in a storage roof or top, designed to accommodate control apparatus or pump columns, should be curbed and sleeved with proper additional shielding to prevent the access of surface or floor drainage water into the structure;

3. Valves and controls should be located outside the storage structure so that the valve stems and similar projections will not pass through the roof or top of the reservoir; and

4. The roof of concrete reservoirs with earthen cover should be sloped to facilitate drainage. Consideration should be given to the installation of an impermeable membrane roof covering.

3.6.7.7. Vents

Finished water storage structures should be vented. Overflows should not be considered as vents. Open construction between the sidewall and roof is not permissible. The requirements for vents are as follows:

1. They should prevent the entrance of surface water and rainwater;

2. They should exclude birds and animals;

3. They should exclude insects and dust, as much as this function can be made compatible with effective venting. For elevated tanks and standpipes, 24-mesh non-corrodible screen may be used; and

4. They should, on ground-level structures, terminate in an inverted U construction with the opening 600 mm to 900 mm above the roof or sod and covered with 24-mesh non-corrodible screen installed within the pipe at a location least susceptible to vandalism.

3.6.7.8. Frost Protection

All finished water storage structures and their appurtenances, especially the riser pipes, overflows, and vents, should be designed to prevent freezing which may interfere with proper functioning.

3.6.7.9. Internal Catwalk

Every catwalk over finished water in a storage structure should have a solid floor with raised edges so designed that shoe scrapings and dirt will not fall into the water.

3.6.7.10. Silt Stop

The discharge pipes from all reservoirs should be located in a manner that will prevent the flow of sediment into the distribution system. Removable silt stops should be provided.

3.6.7.11. Grading

The area surrounding a ground-level structure should be graded in a manner that will prevent surface water from standing within 15 m of the structure.

3.6.7.12. Corrosion Prevention/Reduction

Proper protection should be given to metal surfaces by paints or other protective coatings, by cathodic protective devices, or by both.

1. Paint systems should meet AWWA Standard D102 and NSF Standard 61, and be acceptable to the DOEC. Interior paint must be properly applied and cured. After curing, the coating should not transfer any substance to the water that will be toxic or cause taste or odours. Prior to placing in service, an analysis for volatile organic compounds is advisable to establish that the coating is properly cured. Consideration should be given to 100% solid coatings.

2. Wax coatings for the tank interior should not be used on new tanks. Recoating with a wax system is discouraged, however, the old wax coating must be completely removed to use another tank coating.

3. Cathodic protection should be designed and installed by qualified technical personnel and a maintenance contract should be provided.

3.6.7.13. Disinfection

1. Finished water storage structures should be disinfected in accordance with current AWWA Standard C652. Two or more successive sets of samples taken at 24-hour intervals, should indicate microbiologically satisfactory water before the facility is placed into operation.

2. Disposal of heavily chlorinated water from the tank disinfection process should be in accordance with the requirements of the DOEC.

3. A disinfection procedure (AWWA Standard C652 chlorination method 3, section 4.3) which allows use of the chlorinated water held in the storage tank for disinfection purposes is recommended only where conditions warrant (i.e. where water supply is not abundant, or where large reservoirs would require excessive volumes of water and chlorine. The use of the heavily chlorinated water (depending on the system) may introduce various chlorinated organic compounds into the distribution system.

3.6.7.14. Provisions for Sampling

Appropriate sampling points should be provided to facilitate collection of water samples for both bacteriologic and chemical analyses.

3.6.7.15. Adjacent Compartments

Finished water must not be stored or conveyed in a compartment adjacent to unsafe water when a single separates the two compartments.

3.6.7.16. Basins and Wet-wells

Receiving basins and pump wet-wells for finished water should be designed as finished water storage requirements.

3.6.7.17. Standby Power

The necessity for standby power for a storage facility with pump discharge is dependent on whether the normal power is considered secure. In addition, the volume of elevated storage should be assessed when considering the requirements for standby power.

3.6.8. Water Treatment Plant Storage

3.6.8.1. Backwash Tanks

Backwash tanks should be sized, in conjunction with available pump units and finished water storage to provide the required filter backwash water. Consideration should be given to the backwashing of several filters in succession.

3.6.8.2. Clearwell

Clearwell storage should be sized, in conjunction with distribution system storage, to relieve the filters from having to follow fluctuations in water use.

1. When finished water storage is used to provide contact time for chlorine, special attention must be given to size and baffling;

2. If used to provide chlorine contact time, sizing of the clearwell should include extra volume to accommodate depletion of storage during the night time for intermittently operated filtration plants with automatic high service pumping from the clearwell during non-treatment hours;

3. A minimum of two clearwell compartments should be provided;

4. The overflow pipe should be of sufficient diameter to permit the wasting of water in excess of the filling rate;

5. Consideration should be given to downgrade receiving areas of overflow water. Adequate surface detention should be provided to prevent soil erosion and to provide safe dissipation of chlorine; and

6. The discharge must not be directed to natural water bodies. Discharge in residential areas should be contained to appropriate and controlled storm water channels.

3.6.8.3. Adjacent Compartments

Finished water must not be stored or conveyed in a compartment adjacent to unsafe water when a single wall separates the two compartments.

3.6.8.4. Wet-wells

Receiving pump wet-wells for finished water should be designed as finished water storage structures.

3.6.9. Hydropneumatic Tanks

The use of Hydropneumatic (pressure) tanks, as storage facilities is preferred for small water supply systems. When serving more than 150 living units, however, ground or elevated storage is recommended in accordance with sizing requirements as outlined in Section 3.6.4.

Pressure tank storage is not to be considered for fire protection purposes.

Pressure tanks should meet ASME code requirements or an equivalent requirement of provincial and local laws and regulations for the construction and installation of unfired pressure vessels.

3.6.9.1. Location

The tank should be located above normal ground surface and be completely housed.

3.6.9.2. Sizing

1. The capacity of the wells and pumps in a hydropneumatic system should be at least ten times the average daily consumption rate. The gross volume of the hydropneumatic tank in litres, should be at least ten times the capacity of the largest pump, rated in litres per minute. For example, a 750 L/min pump should have a 7500 L pressure tank; and

2. Sizing of hydropneumatic storage tanks should consider the need for chlorine detention time, if applicable.

3.6.9.3. Piping

The tank should have bypass piping to permit operation of the system while it is being repaired or painted.

3.6.9.4. Appurtenances

Each tank should have a drain, and control equipment consisting of pressure gauge, water sight glass, automatic or manual air blow-off, means for adding air, and pressure operated start-stop controls for the pumps. In large tanks, where practical, an access manhole should be 600 mm in diameter.

3.6.10. Security/Safety

3.6.10.1. Access

Only trained and experienced workers should be allowed to work in water storage facilities.

Finished water storage structures should be designed with reasonably convenient access to the interior for cleaning and maintenance. For in-ground tanks at least two manholes should be provided above the waterline at each water compartment where space permits.

Access manholes in above ground structures should be framed at least 100 mm above the surface of the roof at the opening. For below ground structures access, manholes should be elevated a minimum 600 mm above the top of covering sod;

1. Each of the manhole should be fitted with a solid watertight cover which overlaps the framed opening and extends down around the frame at least 50 mm;

2. Hinged at one side; and

3. Have a locking device.

3.6.10.2. Safety

The safety of employees must be considered in the design of the storage structure. As a minimum, such matters should conform to pertinent laws and regulations of the areas where the reservoir is constructed.

1. Ladders, ladder guards, offset balconies, balcony railings, and safety located entrance hatches should be provided where applicable;

2. Elevated tanks with riser pipes over 200 mm in diameter should have protective bars over the riser openings inside the tanks; and

3. Railings or handholds should be provided on elevated tanks where persons must transfer from the access tube to the water compartment.

3.6.10.3. Protection

All finished water storage structures should have suitable watertight roofs that exclude birds, animals, insects, and excessive dust.

Fencing, locks and access manholes, and other necessary precautions should be provided to prevent trespassing, vandalism, and sabotage as per AWWA standards.

3.7. Watermains

Water distribution systems are made up of pipe, valves, and pumps through which treated water is moved from the treatment plant to domestic, industrial, commercial, and other customers. The distribution system also includes facilities to store water, meters to measure water use, fire hydrants and other appurtenances. The major requirements of a distribution system is to supply each customer with sufficient volume of treated water at an adequate service pressure.

3.7.1. Definitions

Transmission Main – A transmission main is the pipeline used for water transmission, that is, movement of water from the source to the treatment plant and from the plant to the distribution system.

Transmission mains typically do not have service connections

Primary Distribution Main – A primary distribution main is a principal supply pipeline within a distribution system. A primary distribution main can also transport water to adjacent distribution networks.

Distribution Main – A distribution main is the local supply pipeline in the distribution system.

Service Line (Lateral) – A service line is the pipe (and all appurtenances) that runs between the utility's watermain and the customer's place of use, including fire lines.

Service Connection – A service connection is the portion of the service line from the utility's watermain to the curb stop at or adjacent to the street line or the customer's property line.

Average Day Demand – The largest daily rate of flow of water in a year that must be supplied by the water system to meet customer's demands.

Maximum Day Demand – The largest daily rate of flow of water in a year that must be supplied by a water system, to meet customer demand.

Peak Hour Demand – The largest hourly rate of flow of water in a year that must be supplied by a water system to meet customer demand.

Minimum Hour Demand – Can also be referred to as the night demand. It is the lowest hourly rate of flow of water in a year that must be supplied to meet customer demand.

Instantaneous Peak Demand – A short duration high water flowrate that can occur in a water supply system.

3.7.2. Materials

There are a variety of materials in use within water transmission and distribution systems. Typical water pipe material used include:

1. Ductile Iron;
2. Polyvinyl Chloride (PVC);
3. High Density Polyethylene (HDPE); and
4. Concrete Pressure Pipe.

3.7.2.1. Standards, Materials Selection

Pipe, fittings, valves and fire hydrants should conform to the latest standards issued by the CSA, AWWA, NSF, or NFPA, and be acceptable to the DOEC.

The proper selection of water pipe material should take into consideration the following:

1. Working pressure rating;
2. Surge pressure rating;
3. Internal and external corrosion resistance;

4. Negative pressure capability;
5. Ease of installation;
6. Availability;
7. Pipe rigidity with regards to trench conditions; and
8. Ease of repair.

3.7.2.2. Used Materials

Watermains, which have been used previously for conveying potable water, may be reused provided they meet the above standards and have been restored practically to their original condition.

3.7.2.3. Joints

Packing and jointing materials used in the joints of pipe should meet the standards of the CSA/AWWA and the DOEC. Pipe having mechanical joints or plain ends in combination with couplings having slip-on joints with rubber gaskets is preferred. Lead-tip gaskets should not be used. Repairs to lead-joint pipe should be made using alternative methods. Flanged joints should only be used I conjunction with fitting such as valves within a properly constructed chamber.

3.7.2.4. Corrosion Prevention/Reduction

Special attention should be given to selecting pipe materials that will protect against both internal and external pipe corrosion. All products should comply with CSA/ANSI standards.

If soils are found to be aggressive, and the choice of materials is limited and subject to corrosion, action should be taken to protect the watermain and fittings by encasement (wraps, coatings, etc.) and/or provision of cathodic protection. For small copper pipes, sacrificial anodes are recommended.

The design and installation of watermain encasements and cathodic protection should be as per the manufacturer's recommendations.

For water distribution systems with a known corrosion problem or that have a calculated Langelier Index of -2 or below, measures must be implemented to adjust pH levels and eliminate internal corrosion as a result of aggressive water. This is usually accomplished by dosing sufficient amounts of lime in the form of soda ash to buffer the water alkalinity.

3.7.3. Design Criteria – Transmission and Distribution Systems

3.7.3.1. Transmission and Distribution Pipelines

Transmission mains in water supply systems are typically large diameter, carry large flows under high pressure and are long in length, therefore the design activities should address the following:
1. Sizing for ultimate future design flows;
2. Sizing and layout to ensure adequate supply and turnover of water storage facilities;
3. Elimination of customer service take-offs;
4. Minimization of branch take-offs to help maintain flow and pressure control;

5. Air relief at high points and drain lines at low points;
6. Isolation valving to reduce the length of pipe required to be drained in a repair or maintenance shut-down;
7. Potential transient pressures; and
8. Master metering.

Primary distribution mains typically receive flow from transmission mains or pressure control facilities (booster pumps or pressure reducing valve) and supplies water to one or several local distribution systems as well as services to customers. The primary distribution main provides a significant carrying capacity or flow capability to a large area. Key design activities should address:

1. Implementing a minimum “dual” feed system of primary distribution mains to supply large distribution systems;
2. Looping and isolation valving to maintain services with alternate routing in the event of repair or maintenance shutdown.
3. Area metering;
4. Air relief at significant high points;
5. Sizing for future extensions; and
6. Elimination of dead-ends.

Distribution mains typically provide the water service to customers through a network of pipelines feed by the primary distribution mains. Key design activities should address:

1. Looping and isolation valving to maintain service with alternate routing in the event of repair or maintenance shutdown;
2. Adequate valving to provide an efficient flushing program;
3. Elimination of dead-ends; and
4. Pressure Surge Relief (requirements can be addressed by storage in the distribution system or other acceptable methods).

3.7.3.2. Water Demands

Where values for maximum day demand, peak hour demand, and minimum hour (night) demand are not known they can be derived using peaking factors (i.e. applying numerical ratios of the average day demands).

Wherever possible, peaking factors based on actual usage records for a given water supply system should be used in the hydraulic analysis of a water transmission and distribution system. If however such records do not exist or are unreliable, Table 3.7 can be used as a guide.

The peaking factors contained in Table 3.7 are suitable for use in the hydraulic analysis of a municipal system with a variety of uses (residential, public, commercial, industrial). For small water systems where water usage is strictly residential and there are no water usage records, then the Harmon Formula in conjunction with the theoretical water usage of 340 L/cap/day can be used. Water demands and peaking factors for systems containing appreciably large areas of commercial or industrial lands will require an evaluation of water demands based on individual facility users.

Table 3.7
Peaking Factors for Municipal Water Supply Systems

Equivalent Population	Minimum Hour Factor	Maximum Day Factor	Peak Hour Factor
500 to 1000	0.40	2.75	4.13
1001 to 2000	0.45	2.50	3.75
2001 to 3000	0.45	2.25	3.38
3001 to 10 000	0.50	2.00	3.00
10 001 to 25 000	0.60	1.90	2.85
25 001 to 50 000	0.65	1.80	2.70
50 001 to 75 000	0.65	1.75	2.62
75 001 to 150 000	0.70	1.65	2.48
Greater than 150 000	0.80	1.50	2.25

3.7.3.3. Pressure

All transmission mains, primary distribution mains, distribution mains and service mains, including those not designed to provide fire protection, should be sized based on results of a hydraulic analysis of flow demands and pressure requirements.

Transmission and distribution mains should be designed to withstand the maximum working pressure plus pressure surge allowance. Mains should be tested to 1.5 times the working pressure, within a minimum of 520 kPa (75 psi) and maximum of 1200 kPa (175 psi).

The transmission and distribution system should be designed to maintain a minimum pressure of 275 kPa (40 psi) at ground level at all points in the distribution system under normal flow conditions.

Fire flow residual pressure should be maintained at 150 kPa (22 psi) at the flow hydrant, and should be a minimum 140 kPa (20 psi) within the system, for the design duration of the fire flow event.

The normal working pressure in the distribution system should be 410 kPa to 550 kPa (60 psi to 80 psi). The maximum design pressure during minimum demand periods should not exceed 650 kPa (95 psi).

3.7.3.4. Diameter

The minimum nominal diameter of pipe should be as follows:

1. 200 mm for primary distribution mains (300 mm is recommended);
2. 150 mm for distribution mains; and
3. 150 mm for service mains providing fire protection.

3.7.3.5. Small Mains for Domestic Services

1. Small mains for domestic services are acceptable for use in systems not required to carry fire flows;

2. The minimum size of a watermain in a distribution system where fire protection is not to be provided should be a minimum of 75 mm in diameter;

3. Watermains beyond the last hydrant on cul-de-sacs or dead end roads can have pipe sizes from 50 mm down to 25 mm diameter. For water service connections the minimum pipe size required is 20 mm inside diameter;

4. Any departure from the minimum requirements shall be justified by hydraulic analysis and future water use, and can be considered only in special circumstances; and

5. Watermains not designed to carry fire flows are not allowed to be connected to a fire pumper.

3.7.3.6. Velocity

The maximum design velocity for flow under maximum day conditions for transmission mains, primary distribution mains, distribution mains and service mains should be 1.5 m/s. The maximum fire flow velocity should be 3.0 m/s.

Flushing devices should be sized to provide a flow that provides a minimum cleansing velocity of 0.75 m/s in the watermain being flushed.

3.7.3.7. Dead Ends/Looping Requirements

Water distribution systems should be designed to exclude any dead-ended primary distribution mains, and distribution mains unless unavoidable. Appropriate tie-ins (loops) should be made wherever practical.

Where dead-end mains occur, they should be provided with a fire hydrant if flow and pressure are sufficient, or with an approved flushing hydrant or blow-off for flushing purposes. Flushing device shall not be directly connected to any sewer.

3.7.3.8. Fire Protection

All transmission mains, primary distribution mains and distribution mains, including those designed to provide fire protection, should be sized based on a hydraulic analysis to be carried out to determine flow demands and pressure requirements. The minimum size of watermain for providing fire protection and serving fire hydrants should be 150 mm diameter.

3.7.3.9. Fire Pumps

NFPA 20 covers the selection of stationary pumps and installation of pumps supplying water for private fire protection. Items include:
1. Water supplies;
2. Suction;

3. Discharge;
4. Auxiliary equipment;
5. Power supplies;
6. Electric drive and control;
7. Internal combustion engine drive and control;
8. Steam turbine drive and control; and
9. Acceptance tests and operation.

Stored water may be required to meet the demand for fire protection for a given duration. A reliable and "safe" method of replenishment would be required (See Section 3.6).

3.7.3.10. Drain/Flushing Devices

Drain/flushing devices should be placed at significant low points in the transmission system. The drain/flushing devices are required to accommodate flushing during construction, and after a watermain break to drain the pipe for repair.

Where flushing devices are to be installed, they are to be designed in accordance with the requirements of AWWA C651 and due care with respect to: dechlorinating; exit velocity of water during flushing (potential erosion/scour); minimum separation distance from nearest watercourse; storage etc.

Flushing device shall not be directly connected to any sewer.

3.7.3.11. Valves

Valves to be used in water distribution systems shall be manufactured in accordance with recognized standards, such as those prepared by AWWA and as covered in the *Municipal water, Sewer and Road Specifications*.

3.7.3.12. Valve Location

Sufficient valves shall be provided on watermains so that inconvenience and sanitary hazards will be minimized during repairs. Valves should be located at not more than 150 m intervals in commercial districts and at not more than one block or at not more than 240 m intervals in other districts. Where systems serve widely scattered customers and where future development is not expected, the valve spacing should not exceed 1.6 km. In grid patterns, intersecting watermains should be equipped with shut-off valves, as follows, to minimize disruption during repairs:

1. T intersection – at least 2; and

2. Cross intersection – at least 3.

3.7.3.13. Air Relief and Vacuum Valves

Air relief and vacuum valves should be installed, in a chamber, at significant high points in the transmission system and at other such locations as required for efficient operation of the water system.

Automatic air relief valves should not be used in situations where flooding of the manhole or chamber may occur.

The open end of an air relief pipe from automatic valves larger than 50 mm diameter should be extended at least 2.5 m above grade and provided with a screened and downward-facing elbow. The pipe from a manually operated valve should be extended to the top of the air relief chamber.

3.7.3.14. Flow Monitoring

Flow monitoring devices and flow meters should be positioned at key locations along the transmission and primary distribution mains.

3.7.3.15. Crossing Obstacles

Due to geography, parallel services, etc., there will be a variety of physical obstacles, which will result in the watermain crossing obstacles. Considerations include, but are not limited to the following: road crossings, sewers, surface water crossings, and horizontal drillings.

3.7.3.15.1. Road Crossings

It is recommended for all new watermains crossing existing roads and all new roads crossing existing watermains that there is:

1. A minimum cover of 1.8 m from the top of the pipe;
2. Backfill method and material is approved;
3. Drainage is adequate; and
4. Ditches crossing watermains should provide minimum cover of 1.8 m or insulate for frost protection.

3.7.3.15.2. Sewers

See Section 3.7.6.

3.7.3.15.3. Surface Water Crossings

Surface water crossings, whether over or underwater, require special considerations. The DOEC should be consulted before final plans are prepared.

The pipe should be adequately supported and anchored, protected from damage and freezing, and accessible for repair or replacement.

A minimum ground cover of 600 mm should be provided over the pipe. When crossing watercourses, which are greater than 4.5 m in width, the following should be provided:

1. The pipe should be of special construction, having flexible, restrained or welded watertight joints;
2. Valves shall be provided at both ends of water crossings so that section can be isolated for testing or repair; the valves should be easily accessible, not subject to flooding and should be within a properly constructed chamber.

3.7.3.15.4. Horizontal Drillings

Other methods of installation of watermains crossing obstacles or in deep installations include horizontal drilling/boring and installing pipe sections in protective sleeves.

3.7.3.16. Bedding

Bedding material and methodology should be as outlined in Section 02223 of the *Municipal Water, Sewer and Road* Specifications, and should be no less than as recommended by the pipe manufacture.

Do not lay pipe and fittings when the trench bottom is frozen, underwater or when trench conditions or weather are unsuitable.

3.7.3.17. Cover

All watermains shall have a minimum depth of cover not less than the depth of frost penetration, or a minimum of 1.8 m, whichever is greater. If this is not possible, then insulation around the pipe is required. In addition there is a requirement to have sufficient cover over watermains to minimize mechanical loading (See Section 3.7.3.15.1.). It is also recommended that maximum allowable depth be specified.

3.7.3.18. Warning/marker and Detection Tape

Warning/marker and detection tape as specified in the Department of Municipal and Provincial Affairs Water, Sewer and Roads Master Specification Section 02223.2.1 and detailed drawings numbered 0290 and 0300, shall be installed continuously with a minimum 1.0 m overlap at joints above water, sewer, and forcemains. Warning/marker tape shall be heavy gauge polyethylene, 150 mm wide and indicate the service line below. Detectable tape shall be either fabricated of detectable metallic material for underground installation or corrosion resistant insulated wires embedded in warning/marker tape. Detection tapes are intended for pipe location and must be installed above the pipe at an elevation 300 mm below ground surface and be detectable using conventional pipe location apparatus.

3.7.3.19. Thrust Restraint

All tees, bends, plugs and hydrants should be provided with reaction blocking, tie rods or restrained joints designed to prevent movement.

In situations where a watermain installation is above deep fills or parallel to a deep sewer, consideration should be given to using restrained joints.

3.7.3.20. Pressure and Leakage Testing

All types of installed pipe should be pressure tested and leakage tested in accordance with the latest edition of AWWA Standard C600, and as outlined in Section 02713 of the *Municipal Water, Sewer and Road Specifications*.

3.7.3.21. Disinfection

All new, cleaned or repaired watermains should be disinfected in accordance with the latest AWWA Standard C651. The specifications should include detailed procedures for the adequate flushing, disinfection, and microbiological testing of all watermains. In an emergency or unusual situation, the disinfection procedure should be discussed with the DOEC.

3.7.3.22. Commissioning

Following successful testing and disinfection of watermains, the new system should be commissioned with due consideration of resulting pressure and flow changes and other parameters that may be experienced within the water supply system.

3.7.4. Hydrants

Hydrants shall conform to the latest AWWA Standard C502, and shall be ULC and FM approved.

All fire hydrants and flush hydrants should be of "self-draining" Dry Barrel type. In areas having high water tables, appropriate measures should be taken to ensure drainage of the hydrant barrel (pumping or other suitable means).

Watermains which are not designed to carry fire-flows should not have fire hydrants connected to them.

3.7.4.1. Location and Spacing

Hydrants should be provided at each street intersection and at intermediate points between intersections as recommended by the Insurance Advisory Organization (IAO) and the Fire Commissioners Office. In the absence of clear guidance hydrant spacing may range from 100 m to 175 m depending on the area being served and in accordance with IAO and Fire Commissioners Office requirements.

3.7.4.2. Valves and Nozzles

Valves and nozzles shall be as outlined in Section 02713 of the *Municipal Water, Sewer and Roads* Specifications.

Specific requirements should be coordinated with the local fire authority.

3.7.4.3. Hydrant Leads

The hydrant lead should be minimum of 150 mm in diameter. Shut-off valves should be installed in all hydrant leads.

3.7.4.4. Drainage

Attention must be given to drainage of sub-surface hydrant chambers, and only where unavoidable, should pumping chambers dry be specified. Where this is required the hydrants must be clearly marked as non-draining.

Hydrants may also require to be pumped dry when hydrant drains are plugged during freezing weather.

Hydrant drains consisting of a gravel pocket or dry well should be provided unless the natural soils will provide adequate drainage.

Hydrant drains should not be connected to or located within 3 m of sanitary sewers or storm drains.

2.7.4.5. Frost Protection

No type of antifreeze product will be permitted for use as a frost protection for dry barrel fire hydrants situated in high water table areas. An alternative is to plug drain outlets with approved plugs and to drain the hydrant seasonally and after use by pumping out the hydrant.

3.7.5. Valve and Metering Chambers

3.7.5.1. Chamber Construction

Chambers for air relief and vacuum valves, flow monitoring/measuring devices and pressure reducing valves should be:

1. Constructed to provide a watertight structure with easy and safe access;
2. Designed to include watertight gaskets where a pipe passes through a chamber wall; flexible rubber "A-Luk" type for cast-in-place concrete or mechanical expansion insert type for pre-cast concrete;
3. Insulated to ensure adequate frost protection; and
4. Include gravity or pump drainage.

3.7.5.2. Air Relief and Vacuum Valve Chambers

Air relief and vacuum valves should be installed, in a chamber, at significant high points in the distribution system and at other such locations as required for efficient operation of the water system.

Automatic air relief valves should not be used in situations where flooding of the manhole or chamber may occur.

3.7.5.3. Flow Measurement and Meter Chamber

Chambers containing flow monitoring/measurement devices should be located at off-road locations where feasible.

3.7.5.4. Pressure Reducing Valve Chambers

Pressure reducing valve chambers should be designed and constructed to provide:

1. By-pass capability;
2. Isolation valves on the upstream and downstream piping for the pressure reducing valve; and
3. Upstream and downstream pressure gauges.

3.7.5.5. Chamber Drainage

Chambers should be drained, if possible, to the surface of the ground where they are not subject to flooding by surface water, or to underground absorption pits. Drains should be equipped with a backflow prevention device and screening to prevent the entry of insects, birds, and rodents.

In areas where high ground water levels are evident, above water table chambers should be considered.

3.7.6. Separation Distances to Sanitary and Storm Sewers

The following factors should be considered in providing adequate separation:
1. Materials and type of joints for water and sewer pipes;
2. Soil Conditions;
3. Service and branch connections into the watermain and sewer line;
4. Compensating variations in the horizontal and vertical separations;
5. Space for repair and alterations of water and sewer pipes; and
6. Offsetting of pipes around manholes.

3.7.6.1. Parallel Installation

Watermains should be laid at least 3 m horizontally from any existing or proposed sewer. The distance should be measured edge to edge. In cases where it is not practical to maintain a 3 m separation, the DOEC may allow deviation on a case-by-case basis, if supported by data from the design engineer. Such deviation may allow installation of the watermain closer to a sewer, provided that:
1. The watermain is laid in a separate trench, or on an undisturbed earth shelf located on one side of the sewer; and
2. At such an elevation that the bottom of the watermain is at least 450 mm above the top of the sewer, and 300 mm horizontal measured edge-to-edge, or as required by the DOEC.

If separate trenches are used then the soil between the trenches must be undisturbed.

3.7.6.2. Crossings

Watermains crossing sewers should be laid to provide a minimum vertical distance of 450 mm between the outside of the watermain and the outside of the sewer. This should be the case where the watermain is either above or below the sewer with preference to the watermain located above the sewer. At crossings, above or below, one full length of water pipe should be located so both joints will be as far from the sewer as possible. Special structural support for the water and/or sewer pipes may be required.

3.7.6.3. Forcemains

There should be at least 3 m horizontal separation between watermains and sanitary sewer forcemains. When crossing, the watermain should be above the forcemain with a vertical separation of a minimum 450 mm at the crossing.

Where it is anticipated that watermains and forcemains will conflict at the crossings, then the forcemain shall be lowered in order to achieve the minimum 450 mm separation.

The DOEC should be contacted in instances where existing infrastructure does not allow for the watermain to be placed above the forcemain at the required separation.

3.7.6.4. Manholes

Water pipe should not pass through or come on contact with any part of the sewer manhole.

3.7.6.5. Other Sources of Contamination

Design engineers should exercise caution when locating watermains at or near certain sites such as sewage treatment plants or industrial complexes. On site waste disposal facility including adsorption fields must be located and avoided. The engineer should establish specific design requirements for locating watermains near any source of contamination and coordinate planned activities with the DOEC.

3.7.6.6. Water Only Servicing

Where municipal sewers are not provided, watermains must not pass within 15 m of any part of an in-ground sewage disposal system. Water service lines must not pass within 7.5 m of a sewage disposal system. In general, the following conditions should be met in regards to water service lines:

1. There is no joint in the service line between the dwelling and the connection to the curb stop;

2. The groundwater level should not be above the service line; and

3. The service line should be placed upslope of the sewage disposal field.

If these conditions are not met, consideration should be given to increasing the distance between the service line and the sewage disposal system, providing extra protection against contamination.

3.7.6.7. Exceptions

The DOEC must specifically approve any variance from the above requirements when it is impossible to obtain the specified separation distances. Where sewers are being installed and the above requirements cannot be met, the sewer materials should be waterworks grade 1000 kPa (150 psi) pressure rated pipe or equivalent and should be pressure tested to ensure water tightness.

3.7.7. Cross-connection Control

3.7.7.1. Cross-connection Control Programs

There should be no connection between the distribution system and any pipes, pumps, hydrants, or tanks whereby unsafe water or other contaminating materials may be discharged or drawn into the system. A Cross Connection Program should be in place for detecting and eliminating cross connections.

Where there is a requirement for water from the distribution system to be used as part of a process/procedure involving contaminants, measures must be taken to have discontinuous systems (i.e. break-tanks with anti siphon filter pipes or fail-safe backflow devices.

3.7.7.2. Interconnections

The approval of the DOEC should be obtained for interconnections between separate potable water supplies.

3.7.7.3. Backflow Prevention

Backflow prevention devices should be installed on consumer service connections where there is a high risk of contamination of the potable water supply system resulting from backflow or backpressure.

3.7.8. Water Services and Plumbing

3.7.8.1. Plumbing

Water services and plumbing should conform to relevant local and/or provincial plumbing codes, or to the applicable National Plumbing Code. Solders and flux containing more than 0.2% lead and pipe and pipe fitting containing more than 8% lead should not be used.

3.7.8.2. Consumer Connections (Laterals and Curb-Stops)

All consumer connections (laterals) should conform to the following:

1. Minimum cover 1.6 m;
2. Maximum cover 2.0 m;
3. 300 mm minimum horizontal and vertical separation distance from gravity sewer pipes;
4. Minimum 450 mm vertical separation when crossing above a sewer pipe;
5. Minimum separation distance of 3.0 m from outdoor fuel tank;
6. Minimum separation from sewage disposal field of 7.5 m;
7. Single-family residence connections should be minimum 20 mm copper or 25 mm HDPE pipe. Large sizes may be required depending on length of lateral and grade elevations;
8. Solder and flux containing more than 0.2% lead should not be used;
9. Maximum velocity of flow should not exceed 4.5 m/s;
10. There should be not joint between the curb-stop and the building, if possible;
11. A shut-off valve (curb-stop) should be fitted on the street side of the property boundary;
12. An approved metering device should be fitted, where applicable;
13. Backflow prevention devices, when required, should be installed after metering device;
14. Shut-off valve should be fitted before the metering device; and
15. Pressure reducing valves to be fitted as required before metering device.

3.7.8.3. Booster Pumps

Individual booster pumps should not be used for any individual service from the public water supply mains unless approved by the DOEC.

3.7.8.4. Service Meters

Each service consumer connection should be individually metered with an approved metering device, where applicable.

3.7.8.5. Water Loading Stations

Water loading stations prevent special problems since the fill line may be used for filling both potable water vessels and other tanks or contaminated vessel. To prevent contamination of both the public supply and potable water vessels being filled, the following principles should be met in the design of water loading stations:

1. A reduced pressure principle backflow prevention device should be installed on all watermains supplying water loading stations;
2. The piping arrangement should prevent contaminant being transferred from a hauling vessel to other subsequently using the station;
3. Hoses should not be contaminated by contact with the ground;
4. A loading station should be designed to provide access only to authorized personnel; and
5. Access to a loading station should be strictly controlled to minimize water safety and security concerns.

3.7.8.6. Sampling Stations

Dedicated sampling station may be required, within a water transmission and/or water distribution system, to collect water samples as part of the water quality monitoring program. The need for, and the proposed locations of sampling stations, should be discussed with the DOEC.