



Sewage Works Design Standard

EPB 503

November 15, 2012

Foreword

This document replaces Guidelines for Sewage Works Design published by Ministry of Environment on January 2008.

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

- *The Environmental Management and Protection Act, 2010*;
- *The Waterworks and Sewage Works Regulations*;
- Surface Water Quality Objectives;
- Terms of Reference Preparation Guide for Water and Wastewater Work Studies;
- Downstream Use and Impact Study;
- Land Application of Municipal Sewage Sludge Guidelines;
- Treated Municipal Wastewater Irrigation Guidelines;
- Stormwater Guidelines;
- Protocols for the Installation and Sampling of Monitor Wells; and
- Guidelines for Groundwater Monitor Wells at Wastewater Disposal Sites.

The design of a sewage works shall:

- identify all items and factors that need be considered for the construction, operation and maintenance of a sewage works; and
- provide accepted practices suitable for Saskatchewan conditions.

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

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1. Information Submissions for Approvals

1.1 Approval Requirements

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

Typical examples of works requiring construction approvals include:

- wastewater treatment facilities including lagoons and effluent discharge or disposal works;
- sewage collection systems and extensions at systems serving fewer than 5000 people;
- sewage lift and pumping stations; and
- lagoon seepage control works.

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

1.2 Information on Application for Permit

1.2.1 General

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

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

1.2.2 Sanitary Sewage Collection/Pumping and Force mains

A plan of the sanitary sewage collection system, pumping stations and force mains that are connected to the treatment facility and showing, with respect to the collection system:

- (i) the location of the collection system in relation to other underground facilities;
- (ii) the size and type of pipe used in the collection system;
- (iii) the depth of burial of the sewer mains that form part of the collection system;
- (iv) the gradient of the sewer mains that form part of the collection system;
- (v) the locations of manholes that form part of the collection system;

- (vi) the profile elevations for the collection system;
- (vii) the design information of the collection system, including flows, areas served and future areas to be served;
- (viii) description of pumping and other capacities including the mode of operation and emergency or standby features; and
- (ix) description of sewage handling during construction.

1.2.3 Sewage Treatment and Disposal

Site plan drawn to a scale specified on the plan and showing:

- (i) applicant's proposed or existing treatment facility or proposed and existing treatment facilities, as the case may be;
- (ii) the land on which the treatment facility is or will be located and that:
 - a) is owned by the applicant or, if the land is not owned by the applicant, controlled the applicant through an agreement with the owner of the land for its use; and
 - b) may be affected by the operation of the treatment facility;
- (iii) the existing, proposed or existing and proposed residential, industrial, office or institutional developments within one kilometer of the treatment facility;
- (iv) the roads giving access to the treatment facility;
- (v) the topographical elevations contoured to one metre intervals of the area within 300 metres of the treatment facility;
- (vi) a plan of outfall sewers that form part of the sewage works showing:
 - (a) the location of the outfall sewers;
 - (b) the depth of burial of the outfall sewers;
 - (c) the erosion protection details;
 - (d) the diffuser details if one is present;
 - (e) the points of entry to watercourses and lakes that may be affected by the operations of the treatment facility; and
 - (f) the measures to be used to prevent unauthorized entry to the outfall sewers;
- (vii) any groundwater wells within one kilometer of all lagoons; and
- (viii) any watercourses and lakes that may be affected by the operation of the treatment facility.

Process flow diagrams and a hydraulic profile of unit processes in the treatment facility with a written description of the process flow diagrams including:

- the principles of treatment and capacities of individual treatment units of the treatment facility;
- factors used in design;
- nature and quality of sewage including industrial wastes and other contributors to be treated and anticipated sewage flows;
- expected effluent quality and quantity;
- proposed start-up considerations;
- the anticipated method of operation and the arrangement for effluent disposal;
- proposed monitoring features;
- sludge handling and disposal methods;
- operations during construction, where applicable;
- land control and method of control disposal of treated sewage;
- nearby waterbodies and drainage courses;
- the soil and ground water characteristics at the site of all lagoons, effluent irrigation developments and sludge handling and disposal locations; and
- the seepage control and groundwater protection measures for all lagoons, effluent irrigation developments and sludge handling and disposal locations.

The following information for effluent irrigation projects:

- representative chemical and physical descriptions of the soil based on at least A, B and C horizons. The number of sites will be dependent on the size of the area and the uniformity of the soils;
- data on water table locations, together with any available information on underlying aquifers;
- representative analyses of the effluent, including inorganic chemical, bacteriological, nitrogen, phosphorus and organic constituents;
- the proposed use of effluent including intended crops, irrigation system description, irrigation procedure and any special management/operation considerations; and
- a copy of the irrigation agreement, if applicable.

1.2.4 Heritage Resource Review

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

1.2.5 Consultation

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

1.3 Installation of New Sewage Works Technology in Saskatchewan

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

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

1.3.1 Approval by Regulatory History

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

1.3.2 Approval by Verification or Certification

The second option for approving a technology new to Saskatchewan is for the proponent to obtain Verification or Certification by a third-party Evaluation Agency. The Evaluation Agency could be Environmental Technology Verification Program (ETV) or National Sanitation Foundation (NSF) or a similar agency. The Water Security Agency does not endorse any specific testing agency. The Water Security Agency must be involved with design of the approval work under the verification or certification. Approval requires a statement stamped by an experienced professional engineer that the new technology meets all of Water Security Agency's standards, guidelines or requirements for performance and quality as a means to protect public health and the environment. Contact an Approvals Engineer for further information.

1.4 Pilot Plants

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

1.5 Innovative Systems and Planning for Growth

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

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

- obtain opinions from a non-biased expert source;
- the risk of community dissatisfaction with new sewage infrastructure is higher where a treatment technology or similar technology is selected and built based solely on the advice of treatment equipment suppliers;
- an equipment supplier wishes to sell their brand of equipment, and this equipment may not be the best option for the community in practical or financial terms in either the short or long term;
- when selecting a sewage treatment or similar technology, decision makers are advised to *obtain a third-party non-biased engineering consultant to review several treatment options and recommend the best option*;
- the Water Security Agency may not approve expansion such as new subdivisions if that new growth places an unacceptable load on sewage infrastructure;
- incomplete planning at the earliest stages can result in owners investing money in detailed design of new growth such as subdivisions only to have that growth and investment return stopped later due to insufficient sewage infrastructure;
- owners are advised to have an expert determine if their water and sewage infrastructure can support proposed new growth early in the planning stages;
- some facilities that previously used simple sewage lagoons are building small but complex mechanical wastewater treatment plants, and complaints regarding cost and operational difficulty are frequently generated after construction;
- small mechanical sewage treatment plants will typically have significantly greater annual operating costs than a lagoon system; ongoing costs include chemicals, heat, power, parts replacement, sample lab test costs and higher operator costs due to a needed higher-class operator and more time needed to be spent in the plant. At the planning stage, owners should base cost comparisons not just on initial capital build cost, but should compare different options on a Life Cycle Cost which allows for comparison of initial build cost and annual operating cost for different options;
- a non-biased expert should be consulted to select the best sewage infrastructure options for construction, and part of that selection study should be a Life Cycle Cost comparison of different treatment and infrastructure options.

1.6 Terms of Reference

A Terms of Reference (TOR) is a valuable tool used to identify and summarize the content of a study. Creation of a TOR allows the proponent to identify the requirements of the study and can help the consultant ensure that the study result fulfills these requirements.

When a water and wastewater works encounters infrastructure or operational based problems with their system or wants to assess the condition or suitability of their works, an Engineering Investigation is often required. In order to properly identify the components and terms of the Engineering Investigation a TOR should be created by the water or wastewater works owner.

Publication EPB 389 Terms of Reference Preparation Guide for Water and Wastewater Work Studies is provided to water and wastewater works in order to aid in voluntarily creating their own TOR. When using this document it is important to keep in mind that it only provides a general framework. Therefore, when creating a TOR, it is essential to tailor the TOR to the specific situation at hand. In addition, creation of a TOR should be made in consultation with the Water Security Agency to help ensure the TOR identifies the proper issues. For more information please see publication EPB 389 Terms of Reference Preparation Guide for Water and Wastewater Work Studies.

2. Sanitary Sewers

2.1 General

2.1.1 General Aspects

Design and construction of sanitary sewers shall conform to all applicable local or provincial regulations. Because of the difficulties associated with the operation and maintenance of pumping stations or pressure sewerage systems, it is desirable to avoid their use if gravity sewage flow is practical and economically feasible.

2.1.2 Sewage Flows

If practical, sewage flow values for pipe capacities should be established from an appropriate infiltration/inflow study. Consideration of service area characteristics should be included when estimating flow per capita. When available, water consumption for an area should be used to estimate wastewater flow generation. Approximately 60 to 90 per cent of the water consumption reaches the sewer system (the lower percentage is applicable in semiarid regions). Where sewage flow is unknown (new systems, etc.), the average daily domestic wastewater flow including normal infiltration should generally be computed at not less than 450 litres per capita per day (99 gpd/cap). If anticipated infiltration may be significant, an additional allowance should be made for this factor. Sewage flow measurement by flow meter or pump hour meter is strongly recommended.

2.1.3 Waterworks Protection

In general, sewers should be kept as remote as practically possible from public or private water supply wells, surface supplies and waterworks structures.

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

- **Severe** - A cross connection or potential cross connection involving any substance in sufficient concentration to cause death, spread disease or illness or contain any substance which has a high probability of causing such effect. A suitable backflow preventer is an air gap assembly or a reduced pressure zone (RPZ) device. Moderate and minor hazards are also covered by these devices.
- **Moderate** - A cross connection or potential cross connection involving any substance which has a low probability of becoming a nuisance or be aesthetically objectionable if introduced into the domestic water supply. A suitable backflow preventer is a double check valve assembly (DCVA) or similar.

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

Watermains shall cross above sewers with a sufficient vertical separation to allow for proper bedding and structural support of the water and sewer mains. Designs where watermains cross below sewer mains shall be used only where absolutely necessary and use is to be strictly minimized. Where it is necessary for the watermain to cross below the sewer, the watermain shall be protected by providing:

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

No person shall install a watermain in a common trench with a sewer main unless at a service connection and only if the sewer pipe is not under internal pressure and is not located above the water pipe.

Watermains and sewer mains must be separated by a minimum of 2.5 metres (8 ft) horizontally between the pipes, with the area between the pipes constructed to leave as much ground undisturbed as possible while maintaining safety. Unusual conditions including excessive rock, dewatering problems, or congestion with other utilities may prevent the normal required horizontal separation of 2.5 m. Under these conditions, Water Security Agency approval is needed for a lesser separation distance than 2.5 m, provided also that the crown of the sewer pipe is at least 0.5 m below the watermain invert. Where extreme conditions prevent the 2.5 m separation and vertical separation cannot be obtained, the sewer shall be constructed of pipe and joint materials which are equivalent to watermain standards.

2.2 Gravity Collection System

2.2.1 Hydraulic Design

Sanitary sewers shall be designed on a peak design flow basis using values established from an infiltration/inflow study, if practical. In cases where such data are not available, peak design flow may be determined using a peaking factor (ratio of extreme flow to daily average flow) derived from a generally accepted and reliable formula. In determining the required capacities of sanitary sewers, peak inflow from all contributing sources - domestic sewage, industrial sewage or waste flow, inflow and groundwater infiltration shall be considered for the design contributing area. Design criteria for estimating sanitary sewer flows is provided in Section 2.2.5.

It is recommended that no gravity sewer conveying raw sewage should be less than 200 mm (8 inches) in diameter. However, under limited circumstances, sewers of not less than 150 mm (6 inches) diameter may be allowed if the owner can demonstrate that a 150 mm diameter sewer is adequate and will not be detrimental to the operation and maintenance of the sewer system.

Transition head losses and losses from change in direction at manholes, etc., should be considered in collection system design. When a smaller sewer joins a large one, the invert of the larger sewer should be lowered sufficiently to maintain the energy gradient. An approximate method for securing the desired results is to place the 0.8 depth point of both sewers at the same elevation. Oversize sewers will not be approved on new constructions, to justify using flatter slopes. If the proposed slope is less than the minimum slope of the smallest pipe which can accommodate the peak wastewater design flow, the actual depths and velocities at average, and peak wastewater design flow for each design selection of the sewer shall be calculated by the designer.

The hydraulic capacity of a gravity sewer shall be based on consideration of factors such as projected in-service roughness coefficient, slope, pipe material and actual in-service flows. Sanitary sewers shall be designed and constructed with such slopes to give a mean velocity of not less than 0.6 m/s (2 fps) during average flow conditions with due consideration given to actual depth of sewage flowing in the pipe. Slopes slightly less than those required for 0.6 m/s (2 fps) may be considered if the depth of flow will be 0.3 of the diameter or greater for design average flow, and provisions can be made for frequent cleaning. Sewers larger than the minimum size required shall be chosen so that the maximum velocity at the peak design flow is not greater than 3.0 m/s (10 fps) to minimize turbulence and pipe wear, especially where high grit loads are expected. If higher velocities are unavoidable, special precautions shall be taken to protect against displacement and pipe erosion.

All gravity sewers between manholes shall be laid with uniform slopes equal to or greater than the minimum slopes outlined in Table 2.1;

Table 2.1 Minimum Design Slope

Sewer Diameter (mm)	Minimum Design Slope (m/100m)
200	0.40
250	0.28
300	0.22
375	0.15
450	0.12
525	0.10
600	0.08

The Table 2.1 minimum slopes are not based on an assumed specific pipe roughness coefficient, but rather on historical satisfactory operation of sewers meeting or exceeding these slopes under varying flow conditions. For new construction, the pipe slope shall be determined using the minimum pipe diameter necessary for the design volume of wastewater. A manhole outlet pipe diameter shall not be reduced to be smaller than the inlet pipe diameter to compensate for increased slope in the outlet line. In retrofit situations, where the minimum slope cannot be achieved due to site constraints, lower than the minimum slopes may be allowed. In this situation, the owners shall make a commitment to undertake additional operation and maintenance measures to prevent solids deposition in the line.

Although the needed invert drops for the above hydraulic losses will be adequate for sewers with flows at the low end of the acceptable velocity range, the required drops should be specifically calculated for high velocity sewers. The following minimum allowances should be made for hydraulic losses incurred at sewer manholes:

Manhole Type	Loss Incurred
Straight Run	Grade of Sewer
45° Turn	0.03 m (1.2 in)
90° Turn	0.06 m (2.4 in)
Junctions and Transitions	Physical modeling recommended

To allow for gravity drainage from basements, sewer inverts should normally be at least 0.9 to 1.5 m (3 to 5 ft) below basement floor levels.

2.2.2 System Layout

Sanitary sewers shall be located in accordance with all applicable local standards. In general, sewers should be located at or near the centerline of streets/roads to allow servicing to both sides and shall be properly isolated from water mains or other utilities.

It is recommended that sewers 600 mm (24 inches) diameter or less should be laid with straight alignment between manholes. If curved sewer alignments are unavoidable, consideration shall be given to reduce manhole spacing, increased grades and other generally recognized techniques which permit curved sewers to function satisfactorily. Where curved sewers are used, the designer shall not exceed the maximum angle at which the joints remain tight. Curved sewers shall be laid with a radius of at least 60 m unless otherwise supported by manufacturer's specifications. The minimum slopes for curved sewers shall be 50 percent greater than the minimum slopes required for straight runs; this requirement will be waived if the designer submits calculations to demonstrate that increased slope is not required to achieve self-cleansing velocity.

Sewers shall be installed sufficiently deep to be protected from external loading damage, to receive sewage from basements and to prevent freezing. Insulation or an equivalent method shall be provided for sewers that cannot be placed at sufficient depth to prevent freezing. Frost protection criteria for sewers is the same as for water mains. If human bones are encountered during construction, work must stop on the site immediately and the RCMP must be contacted.

Sewers which either cross or run parallel to watercourses or other such features shall be given special attention. Aerial crossings should be avoided, if possible. Inverted siphons, if required, shall have not

less than 2 barrels, with a minimum size of 150 mm (6 inches) and shall be provided with necessary appurtenances for convenient flushing and maintenance. They shall be provided with necessary appurtenances for maintenance, convenient flushing, and cleaning equipment. The inlet and discharge structures shall have adequate clearances for cleaning equipment, inspection, and flushing. Design shall provide sufficient head and appropriate pipe sizes to secure velocities of at least 1 m/s (3 fps) for average design flows. The inlet and outlet details should be so arranged that the flow is diverted to one barrel, and so that either barrel may be cut out of service for cleaning. The vertical alignment should permit cleaning and maintenance.

Sewers on 20 percent slopes or greater should be anchored securely with concrete anchors spaced as follows:

- Not over 11 m (36 ft) centre to centre on grades 20 percent and up to 35 percent;
- Not over 7.3 m (24 ft) centre to centre on grades 35 percent and up to 50 percent; and
- Not over 4.9 m (16 ft) centre to centre on grades 50 percent and over.

2.2.3 Materials/Construction

Sewer pipe, manholes, and sewer appurtenances shall comply with appropriate CSA, ASTM, or similar standards. Pipe selection shall consider local conditions such as character of industrial wastes, possibility of septicity, soil characteristics, exceptionally high external loadings, superimposed live, dead, and frost induced loads, abrasion and similar problems. Sewers shall be designed to prevent damage from superimposed loads. Proper allowance for loads on sewers shall consider soil, type of pipe, width and depth of trench and the need for special bedding, concrete cradles or other special construction techniques, or other special construction shall be used to withstand anticipated potential superimposed loading or loss of trench wall stability. Suitable couplings shall be used for joining dissimilar materials.

Sewer joints shall be designed to minimize infiltration and to prevent the entrance of roots throughout the life of the system. Where sewers are proposed to be located below groundwater table or where they may pass through sensitive groundwater recharge areas, consideration should be given to use of watertight sewers. Sewer pipe bedding shall provide stability and generally conform to the pipe manufacturers recommendations.

For application in which the wastewater is conveyed under pressure, or in special cases involving excessive surcharge such as inverted siphons, pressure pipes should be used. Pipe and joints shall be equal to watermain strength materials suitable for design conditions.

Where necessary, special bedding, haunching and initial backfill, concrete cradle, or other special construction shall be used to withstand anticipated potential superimposed loading or loss of trench wall stability.

Pressure testing of sewers is recommended when high water table is expected or encountered. The infiltration/exfiltration rate for PVC sewer pipes and fittings may not exceed 4.6 liters per mm diameter of pipe per km length per day. Low-pressure air testing may be permitted to verify this joint tightness when tested to a maximum rate of air loss of 0.0015 ft³ per minute per ft² of internal surface. Test methods to the requirements of Uni-Bell Standard UNI-B-6-90.

2.2.4 Manholes

Manholes shall be durable, watertight structures for the purpose of providing convenient access to sewers for observations, inspections, flow monitoring and maintenance operations, at the same time causing a minimum of interference in the hydraulics of the sewer system.

Manholes should be installed at the end of each line, and at all changes in grade, size or alignment. Manholes should be installed at all intersections; and at distances not greater than 120 m (400 feet) for sewers 380 mm (15 inches) in diameter or less; and 150 m (500 feet) for sewers from 460 mm (18 inches) to 760 mm (30 inches) in diameter, except that distances up to 180 m (600 feet) may be considered in cases where modern cleaning equipment for such spacing is provided. Greater spacing may be considered for larger sewers.

Manholes should not be located in areas subject to ponding during rainstorms and snowmelt. Wherever manhole tops may be flooded by street runoff or high water, watertight manhole covers shall be used. Consideration may be given to providing suspended baskets to catch debris that may enter manholes, such as gravel from unpaved streets. Bases shall be watertight and "flow-through" channels through manholes shall be made to conform in shape and slope to that of the sewers.

A suitable drop manhole should be provided for a sewer entering a manhole at an elevation of 600 mm (2 feet) or more above the manhole invert. Drop manholes should be used when invert levels of inlet and outlet sewers differ by 600 mm (2 feet) or more. Where the difference in elevation is less than 600 mm (2 feet), the 0.8 depth point of both sewers should be matched. Drop manholes should be constructed with an outside drop connection. Inside drop connections (when necessary) shall be secured to the interior wall of the manhole and provide access for cleaning. The drop shall be designed to minimize the release of sewer gases. Due to the unequal earth pressures that would result from the backfilling operation in the vicinity of the manhole, the entire outside drop connection shall be encased in concrete.

Cleanouts must be used only for special conditions and may not be substituted for manholes nor installed at the end of laterals greater than 50 m in length.

For sewers up to 1050 mm (42 inches) in size, manholes should be constructed with a diameter of at least 1200 mm (48 inches). For sewers larger than 1050 mm (42 inches), special type manholes or tee riser manholes may be used. Safety and entry requirements shall also be considered when sizing manholes.

Good design practice should prevent the depth of flow from being above the sidewalls of the manhole channeling at all times. Therefore, manhole channels should be a smooth continuation of the incoming pipe, the channel height being one-half the pipe diameter for small sewers or three-fourths the pipe diameter for large sewers (380 mm/15 inches or larger). Manhole benching shall ensure both good footing for workmen and adequate space for minor tools and equipment. Benching shall have enough slope for drainage, however to provide safe footing the slope should not exceed 80 mm/m. No lateral sewer, service connection, or drop manhole pipe should discharge onto the surface of the benching.

Manhole covers shall be designed having the following:

- Adequate strength to support superimposed loads. Frames and covers are usually cast iron, however lighter weight materials may be used where there is no danger of subjection to heavy loads;
- Adequate size to facilitate access of equipment and people;
- A good fit between cover and frame to prevent rattling in traffic;
- Water tightness between cover and frame to reduce infiltration;
- Provision for ease of opening (usually a pick notch to pry the cover loose) and an additional pick hole near the edge of the cover;
- Provision of vent holes; and
- Resistance to unauthorized entry. The principle defense against a manhole cover being lifted by children is its weight, however during infrequent storm events it is possible that surcharge and lifting of the cover can occur. Therefore, provision shall be made in the design to eliminate the possibility of a person falling into the manhole if the cover has been dislodged.

Manhole steps should be either aluminum or galvanized steel, being wide enough to place both feet on one step. Spacing of steps shall be 300 to 400 mm (12 to 16 inches). To reduce the possibility of feet slipping on manhole steps, the safety-drop type of steps are recommended. For those manholes located within a roadway, and where possible, steps should be aligned so that the person exiting from the manhole should do so facing towards oncoming traffic.

Manhole safety landings and ventilation must be provided in accordance with the *Occupational Health and Safety Act*. Frost straps should be provided to hold pre-cast manhole sections together. In areas where the freezing index is greater than 500 freezing degree days Celsius, pre-cast manholes/chambers should have three steel straps extending vertically from top to bottom and held by bolts in the top and bottom sections. When the design freezing index equals or exceeds 1800 freezing degree days Celsius, an additional granular water draining layer at least 0.3 m (12 in) thick should surround the manhole.

2.2.5 Design Criteria for Estimating Wastewater Flows

The following outlines methodologies for quantifying wastewater flows. From a qualitative point of view, owners of wastewater systems are encouraged to develop and implement policies and programs to promote "at source reduction" for any and all contaminants in wastewater. In general, sewer capacities shall have a design life that accounts for the estimated ultimate tributary population, except in considering parts of the systems that can be readily increased in capacity.

2.2.5.1 Residential (Population-Generated)

If no existing data exists, the peak (population-generated) flow for a residential population may be determined by the following formula:

$$QPDW = (G \times P \times P_f) / 86.4$$

where: QPDW = the peak dry weather design flow rate (L/s)

G = the per capita average daily design flow (L/d)

P = the design contributing population in thousands

P_f = a "peaking factor".

The peaking factor (P_f) should be the larger of 2.5 or Harmon's Peaking Factor where:

Harmon's Peaking Factor = $1 + 14/(4 + P^{1/2})$ where:

P = the design contributing population in thousands.

2.2.5.2 Commercial/Institutional and Industrial Determination of Average Flow

For detailed system design, the average wastewater flow from commercial/ institutional and industrial land use areas maybe estimated as set out in Table 2.2 or by actual documented usage.

Table 2.2 Expected Volume of Sewage Per Day

Place	Estimated Sewage Flow Litres/d (gallons per day)
Assembly Halls	32 (7) per seat
Campsite	80 (18) per campsite
Churches	23 (5) per seat
with kitchen	32 (7) per seat
Construction Camps	225 (50) per person
Day Care Centre	113 (25) per child
Dwellings	675 (150) per bedroom
Golf Clubs	45 (10) per member
with bar and restaurant add	113 (25) per seat
Hospital	
(no resident personnel)	900 (200) per bed
Industrial and Commercial Buildings	
(does not include process water or cafeteria)	45 (10) per employee
(with showers)	90 (20) per employee
Institutions	
(resident)	450 (100) per resident
Laundries	
(coin operated)	1800 (400) per machine
Liquor License Establishments	113 (25) per seat
Mobile Home Parks	1350 (300) per space
Motels/Hotels	90 (20) per single bed
Nursing and Rest Homes	450 (100) per resident
Office Buildings	90 (20) per employee
Recreational Vehicle Park	180 (40) per space
Restaurants	
24 Hour	225 (50) per seat
Not 24 Hour	160 (35) per seat

Schools	
Elementary	70 (15) per student
Junior High	70 (15) per student
High School	90 (20) per student
Boarding	290 (65) per student
Service Stations	
(exclusive of café)	560 (125) per fuel outlet
Swimming Pools (Public)	
based on design bathing load	23 (5) per person

* Reproduced from the Alberta Private Sewage Treatment and Disposal Regulations
Table 8.5.B.

Average Flow Generation Estimates for Planning

For system planning purposes, when specific land uses and zoning are unknown and the requirements of 2.2.5.2(1) cannot be defined, the recommended lower limits for estimation of average flow generation (to be used for preliminary planning unless the use of other values is justified with more specific or reliable information) are as follows:

(i) Commercial and Institutional Land Uses

The lower limit for Average Flow Generation should be 40 m³/day/ha (0.46 L/s/ha).

(ii) Industrial Land Uses

The lower limit for average flow generation should be 30 m³/day/ha (0.35 L/s/ha).

Determination of Peak Dry Weather Flow Rate

Peak dry weather flow rates for specific design areas are to be determined by application of a peaking factor (Pf), related to the average flow rate (QAVG in L/s) in accordance with the following expression to a maximum value of 5.0:

$$Pf = 6.659 (QAVG - 0.168)$$

Following from this, the peak dry weather flow rate (QPDW in L/s) may be determined as follows:

$$\begin{aligned} QPDW &= Pf \cdot QAVG \\ &= 6.659 (QAVG - 0.168) \end{aligned}$$

Special Considerations - High-Water-Consumption Land Uses

The foregoing guidelines may not be applied to high water consumption land uses such as heavy industry, meat packing plants, breweries, etc. Detailed analysis of the design requirements specific to each development proposal is required in such cases.

Residential Components of Commercial Developments

Where proposed commercial developments include discretionary residential components, the sanitary flow generation from the residential component should be determined in accordance with Section 2.2.5.1, and is to be included in the determination of the total generation for the development.

2.2.5.3 Extraneous Flow Allowance - All Land Uses

In computing the total peak flow rates for design of sanitary sewers, the designer should include allowances as specified below to account for flow from extraneous sources.

General Inflow/Infiltration Allowance

A general allowance of 0.28 L/s/ha should be applied, irrespective of land use classification, to account for wet-weather inflow to manholes not located in streets and for infiltration flow into pipes and manholes. In addition, a separate allowance for inflow to manholes located in street sags should be added as per the next section.

Inflow Allowance - Manholes in Sag Locations

When sanitary sewer manholes are located within roadway sags or other low areas, and are thus subject to inundation during major rainfall events, the sanitary design peak flow rate should be increased by 0.4 L/s for each such manhole, which is applicable for manholes which have been waterproofed. For new construction, all sanitary manholes in sag locations are to be waterproofed. For planning purposes and downstream system design, where specific requirements for an area are unknown, the designer should make a conservative estimate of the number of such manholes which may be installed in the contributing area based on the nature of the anticipated development, and include an appropriate allowance in the design.

Others

Weeping tile connections to the sanitary sewer system are strongly discouraged and are to be minimized. Local authorities are encouraged to have bylaws prohibiting weeping tile connections to the sanitary system. In areas where weeping tiles are connected to the sanitary sewer system, an additional volume amount, based on on-site measurements or an estimate, shall be included in the design flow. The designer shall also take into account the pipe material and soil type in determining the extraneous flow allowance.

2.2.5.4 Total Peak Design Flow Rates

The total peak design flow rates shall be the sum of the peak dry weather flow rates as generated by population and land use, and the rate of all extraneous flow allowances, as determined for the design contributing area.

2.2.6 Sizing of Sewers

It is normal practice to design sanitary sewers to have a hydraulic capacity such that the sewer is flowing at no more than 80% of the depth when conveying the estimated design peak flow. This is because the maximum velocity is achieved when the flow is at about 0.8 of depth (note: maximum flow occurs when the pipe is flowing at about 0.93 of depth. The reason for this is that as a section approaches full flow, the additional friction resistance caused by the crown of the pipe has a greater effect than the added cross sectional area). Flow rate at a depth of 80% of the sewer diameter is approximately 86% of the sewer full capacity. Therefore, the required flow capacity for sizing of the sewer is computed using the following relationship:

$$\text{Required sewer capacity} = \text{Estimated design flow} / 0.86$$

The Manning equation is generally used in sizing the sewers:

$$Q = (1/n)(AR-S\%)$$

where: Q = Quantity of flow (m³/s)

n = Roughness coefficient (common value used is 0.013; lower value may be used for PVC pipes based on manufacture's recommendation)

A = Cross sectional area of flow (m²)

R = Hydraulic Radius (m)

S = Slope (m/m).

2.3 Pressure System

Pressure sewage collection systems (sometimes referred to as "Modified Sewage Works" or "Sewage Tank Effluent Pump/STEP" systems), where individual contributors pump partially treated sewage into a public pressure main, may be considered for small installations where topographical or other constraints make the use of preferred gravity sewers not feasible. Public mains should have sufficient capacity to accommodate pumpage with no disruption in service with due consideration for coincidental contributors.

System designs shall consider pressure limitations of joints, tees, fittings, etc. Backflow preventers shall be installed on all service lines and a sufficient number of isolation/shut-off valves shall be provided to minimize inconvenience during service repairs. System designers must specify the maximum power rating of pumps on the system to avoid individual pumps from overpressuring the system.

All valves, piping, fittings, appurtenances shall be of high quality durable material, capable of withstanding service pressures and conforming to applicable CSA, AWWA, ASTM or CGSB standards. Piping shall be

installed at an adequate depth to prevent freezing and/or damage from other activities. In all other respects, design of Modified Sewage Works shall ensure that all environmental and health conditions will be safeguarded. Pressure sewer systems should be laid out taking the following into consideration:

- Branched layout rather than gridded or looped;
- Maintenance of cleansing velocities especially when grinder pump type pressure sewers are used;
- Minimizing high head pumping and downhill flow conditions;
- Locating on lot facilities close to the home for ease of maintenance; and
- Providing each home its own tank and pump.

3. Sewage Pumping Stations

3.1 General

3.1.1 Location

Sewage pumping station structures and electrical/mechanical equipment shall be protected from physical damage and shall be located and designed to remain fully operational during 1:100 floods.

During preliminary location planning, consideration shall be given to the potential of emergency overflow provisions and, as much as practically possible, the avoidance of health hazards and adverse environmental effects.

3.1.2 Types

The type of sewage pumping station shall be selected on the basis of such considerations as reliability and serviceability; operation and maintenance factors, relationship to existing stations/equipment, sewage characteristics, flow patterns and discharge and long-term capital, operating and maintenance costs. For large main pumping stations, wet well/dry well type stations are recommended. For smaller stations and in cases for which wet well/dry well types are not feasible, wet well (submersible) pump stations may be used if pumps can be easily removed for replacement or repairs.

3.1.3 Operations

Ease of operation, maintenance and spare part acquisition shall be considered during the design of pumping stations. Provision should be made to facilitate removal of pumps, motors and other mechanical and electrical equipment.

For the long-term use of operating personnel arrangements shall be made for provision of well documented and durably bound operation/maintenance manuals. The manuals shall contain at a minimum:

- a full description of the entire mechanical and electrical installations;
- operational procedures;
- recommended lubrication and maintenance schedules for each piece of equipment;
- list of equipment warranties and their expiry dates;
- a list of spare parts for each piece of equipment;
- emergency procedures; and
- other equipment information.

3.1.4 Safety

Suitable and safe means of access shall be provided to dry wells and to wet wells requiring maintenance or inspection. Stairways are preferable to ladders. All ladders, side rails, ventilation, handrails, platforms, etc. shall be designed and constructed in accordance with applicable occupational health and safety legislation and regulations. Adequate lighting must be provided. Ventilation is a key component of a safe sewage pump station.

The design and installation of all equipment including electrical equipment, lighting, wiring, etc. and all gas-fired heating equipment shall be made to applicable codes, legislation and approval requirements. Every water outlet, or any of its component parts that may come in contact with sewage in a sewage works, must be equipped with a backflow prevention device that prevents the flow of sewage into the water outlet under any conditions. A Severe level of cross connection hazard exists at sewage pump station wells supplied from a potable water system. A suitable backflow preventer is an air gap assembly or a reduced

pressure zone (RPZ) device. Designers shall perform a cross connection study on all new or upgraded pump stations.

A sewage lift station is a hazardous confined space as defined in the Occupational Health and Safety Act and Regulations, 1996. As such, worker entry into the space is regulated by sections 266-275 and other sections. There must be a hazardous confined space entry plan prepared, materials and equipment obtained to safely enter the space, and workers trained on the safe work procedures, personal protective equipment required, and a system of rescue in place prior to any worker entering the space. In addition to the regulation, guidance on best practices can be found in the CSA standard Z1006-10.

3.2 Structures

3.2.1 Wet Wells

Wet well capacity shall be based on consideration of the volume required for pump cycling; dimensional requirements to avoid turbulence problems, the vertical separation between pump control points, inlet sewer elevation(s), capacity required between alarm levels and basement flooding and/or overflow elevations; etc. To avoid septicity problems, wet wells should not provide excessive retention times. Wet wells with a retention time of over 30 minutes are not recommended in residential areas without additional odour control devices as large wet wells can create anaerobic odour issues.

Depending on the characteristics of the sewage, type of pumps, etc., consideration should be given to the need for trash racks or screening. If trash racks or screens are deemed necessary to protect pumps, etc., due consideration should be given to their accessibility and ease of cleaning and maintenance.

Where practical and economically feasible, separate access to the wet well should be provided. Wet wells should be completely separate from the dry wells including dry well superstructures. In cases of a connected superstructure, the area over each well in the superstructure shall be separated by a wall with an exterior door to each area.

The wet well should be designed to prevent solids deposition and to minimize the production of gas and odour. Consideration should also be given to grease removal. Where provision for dumping of hauled liquid wastes is required, a separate manhole complete with screening protection, should be considered.

Where condensation may cause access or corrosion problems at the top of wet wells, consideration should be given to providing heating and air exchange facilities. Due consideration should be given to the selection of materials because of the presence of hydrogen sulphide and other corrosive gases, greases, oils and other constituents in sewage. Materials and designs shall provide stability, durability, structural integrity and water-tightness.

3.2.2 Dry Wells

Due consideration shall be given to protecting the electrical control equipment from excess moisture and waterproofing, etc., to keep dry wells as moisture-free as practically possible. Separate sump pump(s) complete with check valving should be provided in dry wells to remove leakage or drainage, with the discharge to the wet well located as high as possible. All floor and walkway surfaces should have adequate slopes to a point of drainage.

Heating and air exchange shall be provided as required for operating ease and to prevent potential freezing problems due to condensation.

Dry well structures shall be designed and constructed of durable materials in accordance with the latest edition of the National Building Code and/or its supplements, giving due consideration to potential corrosion.

3.2.3 Large Diameter Piping for Sewage Storage

Buried large diameter piping used as a sewage storage device is periodically proposed as an alternative to a sewage pump station and forcemain. Large diameter pipes used for sewage storage tend to be retrofitted into older neighborhoods that experience flooding during periods of high infiltration and inflow. Use of large diameter piping as a sewage storage device is not recommended as a typical sewage flooding solution within new builtup urban centers and these systems must be used with caution in any situation.

Large diameter pipe systems used to store sewage shall be designed and operated to pose the same or less risk to the environment and public health as a sewage lift station and forcemain system; designers of these systems must provide a statement to that effect.

Large diameter piping sewage storage devices shall be located a minimum of 100 metres from the nearest residence; smaller buffer zones may be allowed if dedicated odour control works are in place and all other design requirements are met including any odour controls needed due to extended retention times, air quality monitoring, permanent or portable ventilation, bypass, safe worker access during routine and flood events, and protection of the public during routine operations and during flooding events. The local area flooded by a 1:100 return event of sewage flow shall be fenced and signed to prevent public access. The area flooded by a 1:100 return event of sewage and run-in surface water shall have land control by the owner of the piping works. All large diameter piping projects intended for sewage storage shall include a plan for disinfection and cleanup of the area after a flood event results in sewage external to the piping.

3.2.4 Equipment

Due consideration shall be given to ease of operation, inspection and maintenance of equipment. Provision should be made to facilitate removal of pumps, motors, and other mechanical and electrical equipment. For dry well installations, it is recommended that lifting beams with permanently attached trolleys be provided to facilitate pump/motor assembly removal. Guide rail assemblies, or other practical methods should be provided to facilitate the removal and replacement of submersible pumps and motors.

3.2.5 Ventilation

A pumping station that is a part of a sewage works must have mechanically forced air ventilation. Permanent ventilation shall be provided for all sewage pumping stations and there shall be no interconnection between the wet well and dry well ventilation systems. Designers must undertake calculations showing adequate well ventilation rates. The volume of air to be exchanged cannot include a deduction for any liquid but the volume of fixed equipment may be deducted.. The following minimum air change rates are required to provide adequate ventilation, including at small package-type sewage pump stations:

Wet Wells

Wet well ventilation may be either continuous or intermittent. Ventilation, if continuous, shall provide at least 12 complete air changes per hour; if intermittent, at least 30 complete air changes per hour shall be provided. Air should be forced into the wet well by mechanical means rather than exhausted from the wet well. Where exhaust ventilation is proposed, other measures shall be provided to ensure that contaminants such as sewer gas are not drawn into the wet well while the ventilation system is running.

Dry Wells

Dry well ventilation may be either continuous or intermittent. Ventilation, if continuous, shall provide at least 6 complete air changes per hour; if intermittent, at least 30 complete air changes per hour shall be provided. A system of two-speed ventilation with an initial ventilation rate of 30 changes per hour for 10 minutes and an automatic switch-over to 6 changes per hour may be used to conserve heat where safe.

In lieu of permanently-installed ventilation equipment, portable ventilation equipment can be substituted for use at submersible pump stations and at wet wells with no permanently installed ventilation equipment only where the largest pump is 5 kW or less.

Switches for the operation of ventilation equipment shall be plainly identified and located within arm's reach of the pumping station entry way. All intermittently operated ventilation equipment should be interconnected with the (required) well lighting system, such that the lights cannot be operated without engaging the ventilation equipment.

Positive pressure ventilation is preferred, but ventilation must avoid dispensing contaminants throughout other parts of the pumping station. Provision for heating of intake air is recommended. Vents shall not open into a building or connect with a building ventilation system.

Fresh air should be forced into wet wells at a point about 30 cm above the expected high liquid level, with provision for emergency automatic blow-by to elsewhere in the well, should the fresh air outlet become submerged. This blow-by may be achieved by a small vent hole at a higher elevation in the vent supply pipe.

Ventilation of separate wet wells without pumps shall be provided by a minimum of either convective or mechanical means. Convective ventilation pipes shall be 'goose-necked' and provided with an insect screen at the exterior end.

3.3 Pumps

3.3.1 Units/Capacity

Pump capacities shall be based on hydraulic analysis considering all factors such as inflows; anticipated expansions, peaking factors, system hydraulic characteristics, etc. Special attention should be paid to pumping installations which must pump against high heads.

A pumping station designed for more than 4 L/s (50 gpm) or being the only pumping station in a sewage works shall have at least 2 sewage pumps. For stations using 2 pumps, each pump should be of the same capacity and each should be capable of pumping the anticipated peak sewage flows. (Both pumps operating in parallel should be capable of pumping an occasional short-term inflow which may exceed anticipated peak flows).

For stations which require 3 or more pumping units, the stations should be designed to fit actual flow conditions and should be of such capacity that with any one pump out of service, the remaining pumps will have the capacity to handle maximum sewage flows.

In certain instances, such as pumping stations discharging directly to mechanical sewage treatment plants or into other pumping stations, some means of flow pacing may be required. This could be provided by various means, such as variable speed pumps, depending on the degree of flow pacing that may be required.

For pumping stations using suction lift pumps, special attention should be paid to all elements of design (NPSH, friction and other hydraulic losses, etc.) to assure satisfactory performance under all possible operating conditions.

For very small pumping stations, consideration may be given to use of only one pump, except that a replacement pump or portable stand-by equipment shall be provided.

3.3.2 Piping/Controls

For pumping raw sewage, suction and discharge piping should be sized to accommodate anticipated peak flows with velocities ranging from 0.8 m/s to 2.0 m/s (2.6 to 6.6 fps). Where feasible, velocities at the low end of the range are preferable. Consideration should be given to providing access ports for sampling, swabbing and/or flushing, discharge pressure gauge(s), etc.

Where applicable and for ease of operations, consideration should be given to providing suitable shut-off valves on the suction line of each pump. Suitable shut-off and check valves should be placed on the discharge line of each pump. If possible, check valves should not be placed on the vertical portion of discharge piping. Valves should be capable of withstanding normal pressure and water hammer.

Pump control floats, etc., should be located away from turbulence of incoming flow and pump suction. Control systems should have provisions to automatically alternate the pumps in use. Electrical control panels should be placed outside of wet wells and conform to all local and provincial electrical safety standards.

Alarm systems should be incorporated into the design of pumping stations and should consider the size of the station, the degree of protection required, overflow provisions, availability of operation and emergency personnel, etc.

Due consideration shall be given to providing corrosion protection of all piping/control elements. Installation of a flow meter will give an accurate record of how much flow is being processed through the system. Flow measurement devices should be considered for all stations and are required for main sewage pumping stations and stations having more than two pumps. Installation of an hour meter on each motor will give a reasonable record of how often each motor is cycling; and hence, the amount of sewage being pumped through the system. The minimum requirement for all sewage pump stations is an hour meter designed to measure estimated total volume pumped.

3.4 Emergency Operation

Pumping stations (and collection systems) should be designed to prevent by-passing of raw sewage. New pump stations and collection systems that require or are allowed a bypass or high-level overflow system must be designed to transfer a minimum of the 1:100 return sewage flow with no bypass. For projects where a bypass is part of the design, designers are to examine downstream water uses and impact to the environment and public health to determine if a bypass is feasible or if a bypass is not to occur or if treatment of the bypass liquid is required. Use of off-stream storage systems that prevent bypass to waterbodies and drain back into the pump station is encouraged and should be considered during design of all bypass systems. Pump stations shall be designed to ensure continued operation during a 1:100 flood event considering external and internal liquid contribution.

For use during possible periods of extensive power outages or uncontrolled storm events, consideration shall be given for alarm systems and emergency power generation in order to prevent back-up of sewage into basements, or other discharges which may cause severe adverse impacts on public interests, including public health and property damage.

Standby power should be considered for all pumping stations, particularly main pumping stations. Standby power may be provided by means of an emergency standby generator powered by either a diesel engine, a gasoline engine, a natural or propane gas engine or by an auxiliary drive system powered by any of the foregoing primary power sources. For smaller stations, portable generators or portable gasoline or diesel engine driven pumps may be satisfactory. The method of providing standby power should be capable of operating enough pumps to handle peak sewage flows.

3.5 Force Mains

3.5.1 Location

Location of force mains and their appurtenances shall take into consideration accessibility for operation, maintenance and ease of repair during emergency situations. Valves, air release valves and flushouts shall be placed at appropriate locations and adequately marked.

Force mains entering a gravity sewer should enter at a point not more than 600 mm (2 feet) above the flow line of the receiving manhole. Force mains terminating in a sewage lagoon shall be fitted with a valve prior to entering the lagoon.

Force mains shall be laid at a suitable depth for protection from heavy external loads. The depth below final surface grade should be sufficient to avoid freezing.

3.5.2 Materials

Force mains and appurtenances shall be constructed of suitable durable materials conforming to applicable CSA, AWWA and ASTM standards. The forcemain and station piping shall be designed to withstand water hammer pressures and associated cyclic reversal of stresses that are expected with the cycling of wastewater lift stations. Surge protection systems shall be evaluated.

3.5.3 Capacity/Valving

Force mains should be sized considering life cycle friction factors to meet peak flows with velocities in the range of 0.6 m/s to 1.6 m/s (2.0 to 5.2 fps) with the lower level preferred for the initial design phase. Minimum velocity in a force main is 0.6 m/s (2.0 fps). Minimum diameter should be 100 mm (4 inches), except in special cases where calculations demonstrate that the velocity may not be sufficient to avoid solids deposition.

Appropriate air release valves shall be positioned at proper points in the forcemain to prevent hydraulic problems and air locking. The forcemain configuration and head conditions shall be evaluated as to the need for and placement of vacuum relief valves. Forcemains should be graded to facilitate placement of valves, flushouts and appurtenances.

4. Sewage Treatment

4.1 General

4.1.1 Approvals and Discharge Quality Limits

During the investigation for sewage treatment facilities, the requirements of other administrative authorities with respect to environmental impact assessments, zoning, planning, land use, etc. shall be reviewed and applicable consultation undertaken. As well, the effect on potentially impacted landowners and the environment shall be addressed and resolved. Required approvals from other authorities should be obtained as soon as possible. Where the use of non-owned external treatment facilities are proposed, a long-term agreement shall be obtained which defines rights and responsibilities between those parties that conforms to existing law.

The design treated effluent quality for a wastewater treatment facility shall be based on the more stringent quality resulting from a serial evaluation of the following;

- The provincial minimum requirement for wastewater treatment and effluent discharge quality as seen in Sections 11.1 and 11.2 and 12 of The Waterworks and Sewage Works Regulations for non-continuous discharge to a water not frequented by fish or for reuse by irrigation or evaporation or any other discharge not to a water, where downstream use impacts are known and mitigated. A Downstream Use and Impact Study is not required;
 - o Sections 11.2 and 12 of The Waterworks and Sewage Works Regulations are summarized as: all sewage treatment facilities in a sewage works must include a secondary treatment process that produces effluent with no more than 30 milligrams per litre of BOD₅, 25 milligrams per litre of CBOD₅ and 30 milligrams per litre of total suspended solids; OR have a minimum of two basins in series and are designed and constructed in accordance with the requirements set out in Table 2 of The Waterworks and Sewage Works Regulations (reproduced in this standard as table 4.4);
- The requirement for wastewater treatment and effluent discharge quality as seen in Sections 11.1 and 11.2 and 12 of The Waterworks and Sewage Works Regulations for non-continuous discharge to a water not frequented by fish or for reuse by irrigation or evaporation or any other discharge not to a water, where downstream use impacts are not known. A Downstream Use and Impact Study is not required;
 - o Sections 11.2 and 12 of The Waterworks and Sewage Works Regulations are summarized as: all sewage treatment facilities in a sewage works must include a secondary treatment process that produces effluent with no more than 30 milligrams per litre of BOD₅, 25 milligrams per litre of CBOD₅ and 30 milligrams per litre of total suspended solids; OR have a minimum of two basins in series and are designed and constructed in accordance with the requirements set out in Table 2 of The Waterworks and Sewage Works Regulations (reproduced in this standard as table 4.4);
- The requirement for wastewater treatment and effluent discharge quality as seen in Sections 11.1 and 11.3 of The Waterworks and Sewage Works Regulations for continuous or non-continuous discharge to a water frequented by fish, where other downstream use impacts are known and mitigated. A Downstream Use and Impact Study is not required. A study to determine the site-specific effluent limits of Section 11.3 is required;
 - o Section 11.3 of The Waterworks and Sewage Works Regulations is summarized as: all sewage treatment facilities in the sewage works include a treatment process that produces effluent with no more than 30 milligrams per litre of BOD₅, with no more than 25 milligrams per litre of CBOD₅, with no more than 25 milligrams per litre of total suspended solids, with no more than 0.02 milligrams per litre of total chlorine residual, that is not acutely toxic at the point of discharge, that is not chronically toxic beyond the mixing zone, and that does not contain un-ionized ammonia in excess of 1.24 milligrams per litre (expressed as nitrogen at 15 degrees centigrade, plus or minus one degree centigrade);
- The requirement for wastewater treatment and effluent discharge quality as seen in Sections 11.1 and 11.3 of The Waterworks and Sewage Works Regulations for continuous or non-continuous discharge to a water frequented by fish, where other downstream use impacts are not known. A Downstream Use and Impact Study is required to determine any additional limits or mitigation other than those covered by Section 11.1 and 11.3. A study to determine the site-specific effluent limits of Section 11.3 is required.

- o Section 11.3 of The Waterworks and Sewage Works Regulations is summarized as: all sewage treatment facilities in the sewage works include a treatment process that produces effluent with no more than 30 milligrams per litre of BOD₅, with no more than 25 milligrams per litre of CBOD₅, with no more than 25 milligrams per litre of total suspended solids, with no more than 0.02 milligrams per litre of total chlorine residual, that is not acutely toxic at the point of discharge, that is not chronically toxic beyond the mixing zone, and that does not contain un-ionized ammonia in excess of 1.24 milligrams per litre (expressed as nitrogen at 15 degrees centigrade, plus or minus one degree centigrade);
- o In addition, effluent quality limits shall accommodate and mitigate findings of the Downstream Use and Impact Study.

Any discharge that exceeds 15 days is considered to be a continuous discharge. Owners and designers of sewage works can undertake the above studies and propose effluent quality limits to the Water Security Agency. It is strongly recommended that before any such studies are undertaken that the owner or designer consult with the Water Security Agency who may have existing information and direction to fit the studies. Before proceeding with preliminary design of any sewage treatment works, owners are required to contact the Water Security Agency for approval of effluent quality limits.

The Downstream Use and Impact Study (DUIS) defines the overland downstream discharge path of the treated effluent. The study will identify the uses and users in the downstream environment, and identify potential downstream impacts that could be caused by the discharge of treated effluent. The uses that should be addressed in the DUIS are typically those found in the Surface Water Quality Objectives (SWQO), however additional uses may be of concern and are to be addressed in the relevant study to set effluent quality limits.

The DUIS does not need to be a lengthy document, and the focus of the document should be on the downstream uses and the potential impacts to these uses caused by the proposed effluent discharge. Additional information on DUIS can be found in the publication "Downstream Use and Impact Study".

4.1.2 Process Selection

A process shall be capable of providing the necessary treatment and effluent discharge control to protect the adjacent and receiving environment. During selection of a process type, due consideration shall be given to:

- ability of the treatment process to meet effluent quality limits approved by the Water Security Agency.
- the suitability of the process in terms of operational, maintenance and financial capabilities;
- the characteristics of the sewage including present and projected flows and quality trends, ease of treatment and the existence of sewer use bylaws;
- the results of any treatability or pilot plant studies;
- operational flexibility, potential increased treatment modifications; and
- reliability of the process and the potential for malfunctions or bypassing needs.

4.1.3 Performance Guidelines

Table 4.1 lists expected effluent quality produced by well operated treatment facilities treating typical municipal sanitary sewage. The table can be used to illustrate potential effluent quality for selected processes and as a guide for performance comparisons. Specific facilities may have different treatment objectives and quality requirements such as CBOD₅.

Table 4.1 Sewage Treatment Processes – Typical Effluent Quality

Process	BOD₅ mg/L	TSS mg/L	Total P mg/L	Total N mg/L	Total Coliforms/ 100 mL
Primary (incl. anaerobic lagoons) with phosphorus removal	75-150 45-85	50-110 25-50	5-7 1-2	25-45 20-40	$>2 \times 10^6$ $>2 \times 10^5$
Secondary Biological (Mech.) Aerated Lagoons Facultative Lagoons - Spring - Late Fall	10-25 15-30 25-70 10-30	10-25 20-35 20-60 10-40	3.5-6.5 4-7 3.5-7 2-5	15-35 20-40 20-35 5-20	2×10^4 - 2×10^5 2×10^3 - 2×10^5 $<2 \times 10^3$ - 2×10^5 2×10^2 - 2×10^4
Advanced Secondary with chemical treatment (phosphorus control)	5-15	10-30	0.5-1.5	15-35	2×10^2 - 2×10^4

4.1.4 Location

Siting considerations shall include:

- isolation and buffering adequacy from existing and reasonably foreseeable development;
- present and planned land use compatibility;
- prevailing winds;
- year round accessibility for vehicular traffic;
- protection from flooding;
- suitability for expansion;
- effluent discharge arrangements;
- topography, soil conditions and groundwater regime; and
- future servicing feasibility.

Sewage works, both mechanical and lagoons, emit odour that has shown to persist at some distance from the source. As seen in Section 10 and Table 1 of The Waterworks and Sewage Works Regulations, a buffer zone is the physical distance between (or setback from) the nearest liquid surface or mechanical facility containing sewage to the closest corner or side of the nearest single isolated residence, built-up residential area (2 or more residences in any one-hectare area), institutional area or commercial area.

The buffer zone helps to foster a living and work environment that is generally free of sewage works odours and minimizes health concerns. The setback distances have been found to reasonably limit the number of complaints received from the public about the sewage works odour, indicating that the odour was unable to persist regularly at such distances from the source.

The location of a sewage works with respect to prevailing wind direction, and the presence of wind blocks, has an effect on the ability of the odour to persist at a distance from the source. Enhanced vegetative surround has been proven to abate odour. The siting of a sewage works in a downwind direction (according to wind rose data) from a development lessens the likelihood that the odour will spread toward the development. The above odour abating factors, coupled with dedicated odour control equipment or a history of no odour complaints, may allow for a reduced the buffer zone requirement on a case by case basis, which is reflected in Section 10 and Table 1 of The Waterworks and Sewage Works Regulations. Proposed use of any buffer zone reducing factors must be listed and explained in relevant design documents and must be agreed to by the Water Security Agency. A summary of allowable buffer zones from *The Waterworks and Sewage Works Regulations* is shown in Table 4.2.

Table 4.2 Facultative Lagoon and Mechanical Treatment Facility Buffer Zone Table

	Facultative Lagoon Buffer Zone (Metres)	Mechanical Sewage Works Buffer Zone (Metres)
Single Isolated Residence	300	300 ⁽¹⁾
Built-up Residential Area	550 ⁽²⁾	300 ⁽¹⁾
Institutional	550 ⁽²⁾	300 ⁽¹⁾
Commercial (with no built-up residential area)	300	300 ⁽¹⁾

⁽¹⁾ Minimum buffer zone is 150 metres with advanced odour control facilities.

⁽²⁾ A 50 metre buffer zone reduction if any of the following is met, to a minimum buffer zone of 450 metres;

- a) history of no odour complaints;
- b) favourable prevailing spring winds; or
- c) significant wind block

4.1.5 Design Loading

The treatment facility shall be sized to accommodate design peak sewage flows with due consideration for industrial wastes and shock loadings. Sufficient flow and quality data should be obtained to define the nature and characteristics of the raw sewage. The data should be adequately comprehensive and appropriate for design considerations of the treatment process. For new systems relevant analogous information should be obtained.

If information is unavailable, a typical BOD₅ for raw sewage from domestic, commercial, and light industrial sources of 77 grams/capita-day (0.17 lbs/capita-day) may be considered. Trucked or piped raw sewage from septic holding tanks in good condition that are operated properly may have a BOD₅ of 68 grams/capita-day (0.15 lbs/capita-day). Field evaluation of septic haul trucks has shown septic holding tanks that are not in good condition or leaking or poorly operated or contain septage can have a raw sewage that exceeds BOD₅ of 1200 mg/L due to accumulation over time of high-strength wastes in the tank, versus the 200-250 mg/L BOD₅ of typical municipal sewage. Facility designers are recommended to analyze raw sewage BOD₅ at truck haul systems where holding tanks in poor condition or under poor operation are suspect, and to ensure the treatment facilities are designed to operate effectively at those BOD₅ levels. Mechanical and lagoon treatment facility proposals with over 30% of total annual influent derived from haul form septic holding tanks must undertake a minimum of five raw BOD₅ samples taken over time from septic haul tanks as part of the design process.

4.1.6 Plant Facilities

For the design and installation of sewage treatment components and building services, designers must meet applicable codes, legislation and approval requirements. Plant design shall incorporate safety features relevant to the process and as may be required by administrative authorities. Plant building design shall incorporate space for any required proper chemical storage, work and storage areas, personnel and sanitary facilities, laboratory area and office services. Building design and construction should use materials that are suitable for the proposed service and that are easily maintained and cleaned.

Component and equipment layout should be arranged to facilitate operating and maintenance convenience, flexibility and potential installation of future units. Space and proper access should be provided for inspections, maintenance and repair. Provision should be made for equipment removal or replacement. Unit bypasses should be considered to enable removal of a component from service for maintenance or repair purposes.

Suitable water supplies should be provided for potable, sanitary, laboratory, cleaning and equipment purposes. Standby or emergency equipment and power facilities should be considered on the basis of the treatment process, equipment or component integrity and potential impacts in case of failures.

Proper measuring devices and gauges applicable to the process should be provided. Allowance should be made for manual and/or automatic sampling at important junctions in the treatment process. Analytical

equipment should be provided for tests pertinent to the process being used and particularly for use with process control.

Every plant shall have a readily available and comprehensive operations and maintenance manual. It is suggested that the manual include:

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

4.1.7 Colour code for Wastewater Treatment Plant Piping

It is recommended that piping be adequately identified as to contents and direction of flow. Where a facility does not have a standardized coloring or marking code, one should be adopted. The recommended colour code for the Wastewater Treatment Plant Piping as per the "Ten State Standards" is shown in Table 4.3.

Table 4.3 Wastewater Treatment Plant Piping – Recommended Colour Code

Pipes	Colour
Sludge Lines: Raw Sludge Sludge Recirculation or Suction Sludge Draw Off Sludge Recirculation Discharge	Brown with Black Bands Brown with Yellow Bands Brown with Orange Bands Brown
Gas Lines: Sludge Gas Natural Gas	Orange or Red Orange or Red with Black Bands
Water Lines: Non-potable Water Potable Water	Blue with Black bands Blue
Other: Chlorine Sulfur Dioxide Sewage (Wastewater)	Yellow Yellow with Red Bands Gray

The direction of flow and name of contents shall be noted on all lines. The entire length of pipe is to be painted with the recommended colour. Individual bands are to be 25 mm wide and a 25 mm space is to be left between bands. Bands, if necessary are to be located as follows:

- at 9 m intervals, and/or
- where the pipe enters and leaves a room.

4.2 Primary

4.2.1 Pre-Sedimentation

Screening should be provided as the first treatment stage with consideration given to:

- provision of adequate space for servicing, drainage and adequate lighting and ventilation;
- installation of a standby unit;
- separate outside access to equipment installed in a building where other equipment or offices are located;
- protection from freezing for units installed outdoors; and
- provision of adequate means of removing screenings.

To protect equipment and reduce grit depositions in pipes, channels, tanks and digesters, grit removal facilities should be provided. Screenings and unwashed grit should be handled in covered containers and removed to the disposal site daily. Consideration should be given to odour control.

Comminution should be used in plants that do not have primary sedimentation tanks or fine screens and should be provided in cases where mechanically cleaned bar screens will not be provided. Consideration should be given to:

- provision of a screened by-pass channel (the use of the by-pass channel should be automatic at depths of flow exceeding the design capacity of the unit); and
- requirements for location of the equipment in accordance with those for screen devices.

4.2.2 Sedimentation

Plants not having multiple units should include other provisions to assure continuity of treatment. Capacity of units should be designed for peak flow rate with surface overflow rate not to exceed:

- 70 m³/m²-d (1400 g/ft²-d) for tanks not followed by secondary treatment;
- 35 m³/m²-d (700 g/ft²-d) with phosphorous removal using alum or ferric compounds;
- 45 m³/m²-d (900 g/ft²-d) with phosphorus removal using lime;
- 50 m³/m²-d (1000 g/ft²-d) for tanks followed by secondary treatment with waste activated sludge handling in the tanks; and
- 80 m³/m²-d (1600 g/ft²-d) for tanks followed by secondary treatment without waste activated sludge handling in the tanks.

The tanks should be equipped to enhance safety for operators and provided with convenient and safe access to routine maintenance items. Consideration should be given to protect the tanks and machinery from freezing. Covered tanks should have access provided to weirs, scum removal equipment, inlet and outlet. Tanks installed in a building should be provided with adequate lighting and ventilation. Since heating is not economical for a high humidity area, all water pipe and roof drains in the building should be protected from freezing.

Effective scum/sludge collection and removal facilities should be provided. The unusual characteristics of scum and the effect of low temperature, which may adversely affect pumping, piping, sludge handling and disposal should be considered in design. Pumps used for primary sludge should have high suction lift capacity.

4.3 Secondary

4.3.1 Activated Sludge

During selection of the activated sludge process and its various modifications, the following should be considered:

- raw sewage amenability to biological treatment; operational and laboratory control requirements and constraints;
- expected organic and hydraulic loadings including variations;
- treatment requirements, including necessary reduction of carbonaceous and/or nitrogenous oxygen demand;
- sewage characteristics including pH, temperature, toxicity, nutrients;
- maximum organic loading rate;
- minimum hydraulic detention time;
- sludge production; and
- selection of reactor type, including land availability, type of aeration equipment.

Evaluation of aeration equipment alternatives should include the following considerations:

- costs - capital, maintenance and operating;
- oxygen transfer efficiency;
- mixing capabilities;
- diffuser clogging problems;
- air pre-treatment requirements;
- total power requirements;
- aerator tip speed of mechanical aerators used with activated sludge systems;
- icing problems;
- misting problems; and,
- cooling effects on aeration tank contents.

Aeration equipment should be designed for the maximum organic loading and mixing requirements at high temperature conditions with turn-down capability and with motors of adequate horsepower provided for the coldest winter weather. Consideration should be given to standby capacity.

Ample return-sludge pump capacities and pumping rate variability should be provided for the selected process. The waste sludge system should be designed for the maximum sludge production of the process. Waste sludge rate should be able to change to meet the process requirements.

4.3.2 Biological Filters

Consideration for biological filters should include:

- raw sewage amenability to biological treatment;
- impact of coldest influent sewage temperatures on biological treatment effectiveness;
- pretreatment effectiveness including scum and grease removal;
- expected organic loadings, including variations;
- expected hydraulic loadings, including variations;
- treatment requirements, including necessary reduction of carbonaceous and/or nitrogenous oxygen demand;
- sewage characteristics, including pH, temperature, toxicity, nutrients;
- maximum organic and hydraulic loading rates;
- type and dosing characteristics of the flow distribution system;
- type of filter media to be used;
- configuration of underdrain system;
- recirculation rate;
- provision for adequate ventilation;
- freezing problems in winter time; and
- provision for flushing the underdrain system.

Flow distribution system selection should be based on the following;

- ease of cleaning; ruggedness of construction;
- ability to handle large variations in flow while maintaining adequate and uniform flow distribution; and
- corrosion resistance.

4.3.3 Rotating Biological Contactors

Considerations for the rotating biological contactor (RBC) process should include:

- raw sewage amenability to biological treatment;
- pretreatment effectiveness including scum and grease removal;
- expected organic loadings, including variations;
- expected hydraulic loadings, including variations;
- treatment requirements, including necessary reduction of carbonaceous and/or nitrogenous oxygen demand;
- sewage characteristics, including pH, temperature, toxicity and nutrients;
- impact and need for procedures to restart the process after a mechanical failure;
- maximum organic loading rate of active disc surface area; and
- minimum detention time at maximum design flow.

For economy of scale, peaking factor of maximum flow to average daily flow should not exceed 3. Flow equalization should be considered in any instance where the peaking factor exceeds 2.5. All RBC units should be suitably covered.

4.3.4 Sedimentation

The final sedimentation tanks should be used to separate biological particles from treated sewage. The surface area requirements for clarification vary with the settling characteristics of the mixed liquor. Factors which can influence the settling characteristics are chemical addition to the mixed liquor for phosphorus removal and nitrification process.

Plants not having multiple units should include other provisions to assure continuity of the treatment.

Capacity of units should be designed for the greater of the surface area required at peak flow conditions with surface overflow rate or solids loading not to exceed:

- 50 m³/m²-d (1000 g/ft²-d) or 10 kg/m²-hr (2 lb/ft²-hr) for activated sludge with no chemical addition to mixed liquor for phosphorus removal;
- 35 m³/m²-d (700 g/ft²-d) or 10 kg/m²-hr (2 lb/ft²-hr) for activated sludge with chemical addition to mixed liquor for phosphorus removal;
- 30 m³/m²-d (600 g/ft²-d) or 5 kg/m²-hr (1 lb/ft²-hr) for activated sludge with nitrification process; and
- 35 m³/m²-d (700 g/ft²-d) or 5 kg/m²-hr (1 lb/ft²-hr) for extended aeration process with or without chemical addition to mixed liquor for phosphorus removal.

Effective scum/sludge collection and removal facilities should be provided. Sludge withdrawal facilities should be designed to assure rapid removal of the sludge.

Consideration should be given to protect the tanks and machinery from freezing:

- covered tanks should have provisions for access to weirs, scum removal equipment, inlet and outlet; and
- tanks installed in a building should be provided with adequate lighting and ventilation. Since heating is not economical for a high humidity area, all water pipe and roof drains in the building should be protected from freezing.

4.4 Waste Stabilization Ponds (Lagoons)

4.4.1 Types

For the general purposes of these guidelines, waste stabilization ponds (lagoons) may be considered as primary and/or secondary treatment facilities. Treatment may be achieved by anaerobic, facultative, and/or aerated lagoons. Design of treatment with anaerobic lagoons must include a study of odour impacts and suitable buffer zones.

In general, long detention facultative lagoons are considered capable of providing secondary treatment during summer months. Because of operating ease, facultative lagoons are generally considered appropriate for use in treating sewage for small to medium sized installations where appropriate.

Aerated lagoons are lagoons where oxygen is mainly obtained from other than natural means such as diffused air or agitation type aeration systems.

4.4.2 Siting

Lagoon siting shall consider a wide range of pertinent factors such as flood protection, availability and value of suitable land for the proposed site; environmental compatibility of a pond with neighbouring land uses, wastewater characteristics and design loads, effluent quality requirements and disposal alternatives, surface water and runoff; geotechnical conditions, groundwater regimes, all weather vehicle accessibility, expansion potential and any other factors that may affect the feasibility and acceptability of a specific site. Applicable isolation distances and other requirements established by road, highway, railway and other authorities shall be considered.

Waste stabilization ponds in the vicinity of recreational lakes should be sited as far as practically possible from the lake and recreational areas and shall consider applicable shoreline regulations that may currently be in effect. High-use recreational areas on lakes and watercourses should not be used as a discharge location for the treated effluent from any type of treatment plant.

In determining land requirements, due consideration shall be given to municipal expansion, additional treatment units and/or increased waste loadings, ultimate disposal of effluent and remedial measures that may be required to correct potential negative impacts that may result from lagoon operations.

4.4.3 Construction Features

Appropriate sub-surface geotechnical and/or hydrogeological explorations and reports shall be undertaken to establish the suitability of proposed materials to meet anticipated conditions.

A minimum of 3 test holes per site or 1 test hole per 3 hectares (whichever is greater) shall be made to establish soil conditions at the lagoon site. More test holes may be required if complex geological conditions are encountered or if the site is located in an environmentally sensitive area. All test holes shall be dug to at least 4 metres below the proposed lagoon floor elevation. Groundwater information below the lagoon site

including water quality, water levels, direction of flow and gradient may be required for establishing lining requirements as well as for establishing the location of any monitor wells that may be required. A geotechnical report shall be prepared for all proposed lagoon construction and shall contain a recommendation for lagoon liner construction and groundwater monitoring.

Lagoon cells shall be relatively impermeable in accordance with the needs for functional treatment and protection of surrounding land and ground water. Seepage (exfiltration) from a lagoon facility should be limited to no more than 150 mm per year. Greater exfiltration losses may be permitted if it can be demonstrated as discussed in Section 4.9.4 that surrounding land and groundwater will not be adversely affected or other suitable provisions are made to intercept the exfiltration. It is required that field and/or laboratory tests be carried out to establish the hydraulic conductivities of soils at the lagoon site and any proposed soil lining materials. For new lagoon construction areas that are less than 10 ha in size, at least one hydraulic conductivity test per 4 hectares of lagoon area shall be carried out. For lagoon construction areas that are greater than 10 ha in size, at least one hydraulic conductivity test per 5 hectares of lagoon area shall be carried out. For in-situ materials or soil liners an on-site permeability of at least 10 times the laboratory value shall be used to calculate exfiltration losses. If an in-situ liner is proposed then the Water Security Agency must be contacted to establish the number of conductivity tests required to prove the material is adequate. Adequate provisions for monitoring and for exfiltration control measures such as cutoffs, sub-surface drainage interceptors, etc. shall be considered. Where soils, bentonite or synthetic liners are used for seals, the permeability, durability and integrity of the proposed material should be satisfactory for anticipated conditions. Prefilling the pond(s) or other techniques shall be considered in order to protect the liner, prevent weed growth and to protect against freeze-thaw or desiccation of the seal material.

The lagoon bottom should be as level as practically possible at all points and free from organic material. Clay lagoon liners shall be at least 600 mm thick, which can consist of a maximum 150 mm scarified layer and a minimum of an additional 450 mm of compacted clay. The minimum thickness of a synthetic HDPE or equivalent liner is 40 mils (approximately 1 mm). The floor of a lagoon that is lined with a synthetic HDPE or equivalent liner shall be covered with a minimum 300 mm thick layer of fine-grained soil to prevent liner damage. Synthetic HDPE or equivalent liners less than 60 mils (approximately 1.5 mm) thick shall be covered with a minimum 300 mm thick layer of fine-grained soil on the lagoon side slopes in addition to the lagoon floor. A stable and well prepared subgrade and proper membrane installation, with particular emphasis on seaming, is necessary for the successful performance of the liner. A system for venting gas generation beneath the liner should be considered. Synthetic HDPE or equivalent liners shall be installed according to the manufacturer's recommendations with particular attention paid to QA/QC.

All cells containing effluent that does not meet final discharge quality objectives must have an approved engineered liner or an alternate liner approved by the Water Security Agency that is designed with a maximum of 150 mm annual exfiltration. Discharge to an unlined area is allowable only after minimum treatment or discharge quality limits have been met.

The complete waste stabilization pond area shall be enclosed with an adequate fence to prevent entering of the public or livestock and to discourage trespassing. A vehicle access gate of sufficient width to accommodate all equipment should be provided. Access gates should be provided with locks. Fences should be located away from the outside toe of the dyke to facilitate dyke mowing and maintenance operations. Appropriate warning signs should be provided along the fence to designate the nature of the facility and to warn against trespassing.

When it is anticipated that liquid waste may be transported to the lagoon by pump-out truck haulers, suitable means for truck access and tank unloading such as paved chutes should be provided. It is recommended that lagoons that accept hauled sewage have strong controls on access such as keycard locks.

Dykes shall be constructed so the top width is a minimum of 3 m (10 feet) to permit access for maintenance vehicles. Side slopes of dykes should be stable. In general, interior side slopes should not be flatter than 6:1 to control emergent vegetation nor steeper than 3:1 for ease of maintenance. Erosion protection should be provided as may be required with due consideration to all relative factors such as pond location and size, seal material, topography, wave action, prevailing winds, etc. Riprap or other suitable means of erosion control should be considered as a minimum around pipes and inlets. Seeding of slopes is encouraged. Freeboard shall be a minimum of 1 m (3 feet).

Influent lines should be installed using materials and construction methods which are generally accepted for underground sewer construction with due consideration for the quality of wastewater, possibility of septicity, external loadings, abrasion, soft foundations and similar potential problems. Influent lines should be located to minimize short-circuiting. Consideration should be given to the need for multiple inlets, angle of entry into the lagoon, provision of design features which facilitate sludge removal/dispersion and adequate erosion protection such as concrete or riprap at the end of the pipe.

The invert of the last manhole on a gravity outfall line should be at least 0.15 m (6 inches) above the design operating level of the lagoon. Pressure mains terminating in a sewage lagoon shall be fitted with a valve immediately upstream of the lagoon.

Transfer (interconnecting) and discharge piping should allow flexibility of operation, be positioned to avoid short-circuiting, be adequately sized of suitable material and equipped with appropriate controls. Overflow conduits should be provided between cells, but provision of emergency overflows which permit uncontrolled discharge out of the lagoon is discouraged.

4.4.4 Lagoon Monitoring Requirements

A geotechnical report shall be prepared for all proposed lagoon construction. The geotechnical report shall recommend a groundwater monitoring plan or shall clearly state why a groundwater monitoring plan is not required. Where a geotechnical report substantiates the presence of ground water either by test holes or other knowledge, or where any impact to the public or the environment could occur in the event of a leak, then monitoring wells shall be installed and a monitor plan prepared. The minimum number of monitor wells required is three and many lagoons will require more than three. Draft monitor plans shall include preliminary location, depth and size of monitoring wells on drawings and the draft monitor plan submitted for approvals. Final locations, depth and size of the monitoring wells will be shown on "as built drawings" that is to be submitted at the end of the construction project.

Upon completion of lagoon construction, the baseline groundwater quality shall be determined prior to operating the lagoon by collecting and analyzing water samples from monitoring wells. Baseline water samples will be tested for the following parameters: Nitrate Nitrogen, Total Phosphorus; 5 days 20°C Biochemical Oxygen Demand; Fecal Coliform Bacteria; Conductivity at 25°C; pH; Alkalinity; Calcium; Magnesium; Sodium; Bicarbonate; Carbonate; Chloride and Sulphate.

Time frames for the sampling of groundwater monitoring wells after construction and commissioning will be once after two months, six months and a year, and each two years thereafter, or as seen in the Permit to Operate. Thereafter, each monitor well must be sampled at a known frequency for specific parameters outlined in the Permit to Operate. Installation and sampling of monitoring wells shall be performed in accordance with Protocols for the Installation and Sampling of Monitor Wells (WQ 117, 1989) and Guidelines for Groundwater Monitor Wells at Wastewater Disposal Sites (WQ 100, 1987).

4.4.5 Facultative Lagoons

As required by Section 12 of *The Waterworks and Sewage Works Regulations*, if one or more facultative lagoons are used to treat sewage, each facultative lagoon must have a minimum of two basins in series and be designed and constructed according to the requirements of Table 2. Additional cells may be required and the design may include facilities for series and parallel operation for operational flexibility. Sewage treatment facilities designed under Section 11 (2) (a) of *The Waterworks and Sewage Works Regulations* that propose to use facultative lagoons must also use a minimum of two basins in series.

Primary cell loading and secondary cell storage shall conform with Table 2 as required by Section 12 of *The Waterworks and Sewage Works Regulations*. Secondary cell storage design shall not include exfiltration nor shall it include evaporation losses unless the cell is being designed as an evaporation cell. Owners shall ensure that new loads added to the sewage system do not cause effluent quality limits to be exceeded; owner diligence is required when new loads such as subdivision or higher-strength industrial sewage is accepted at any treatment facility. Special consideration should be given to the discharge arrangements and the need for increased storage where required. A summary of the lagoon design requirements from *The Waterworks and Sewage Works Regulations* follows as Table 4.4;

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Table 4.4 Facultative Lagoon Design Requirements and Compliance Timelines

Type of lagoon and discharge method	Primary Basin Loading Design	Combined design storage capacity in all basins other than primary basins	Compliance deadline
Type 1: Existing facultative lagoon that discharges or will discharge via effluent irrigation.	Primary basin surface area sufficient to ensure that a CBOD ₅ of not greater than 25 kilograms/hectare/day and a BOD ₅ of not greater than 30 kilograms/hectare/day	Design storage for 240 days of average day sewage input for the population served.	November 1, 2022
Type 2: Expanded, upgraded or new facultative lagoon that discharges or will discharge via effluent irrigation.	Primary basin surface area sufficient to ensure that a CBOD ₅ of not greater than 25 kilograms/hectare/day and a BOD ₅ of not greater than 30 kilograms/hectare/day	Design storage for 240 days of projected average day sewage input to the population to be served over a projected minimum 20 year design life.	Date on which expansion, upgrade or new lagoon is commissioned.
Type 3: Expanded, upgraded or new facultative lagoon other than Type 1 or Type 2 lagoons.	Primary basin surface area sufficient to ensure that a CBOD ₅ of not greater than 25 kilograms/hectare/day and a BOD ₅ of not greater than 30 kilograms/hectare/day	Design storage for 220 days of projected average day sewage input to the population to be served over a projected minimum 20 year design life.	Date on which expansion, upgrade or new lagoon is commissioned.
Type 4: Existing facultative lagoon other than Type 1 or Type 2 lagoons.	Primary basin surface area sufficient to ensure that a BOD ₅ of not greater than 30 kilograms/hectare/day	Design storage for 180 days of average day sewage input for the population served.	December 5, 2002

For small summer-type operations with a design population below 300, for which 75 per cent of the sewage flow occurs from May to September, the primary cell may be sized on the basis of BOD₅ loading of 55 kg/ha-d (49 lb/acre/day), with the design derived from the average loading for a maximum week. For these small summer-type systems, the second cell shall have sufficient volume to contain the annual flow. Designers are recommended to carefully compare capital cost of this option with a lagoon system based on Table 2 design factors.

The liquid depth for the primary (treatment) cell(s) of a facultative lagoon at design operating stage shall not exceed 1.5 m (5 feet). Due consideration should be given to the anticipated actual conditions under which the lagoon will operate prior to reaching design operating stage and to potential adverse effects (eg. desiccation) that lower initial flows may have on the lagoon. The minimum depth throughout all operating conditions should be maintained at or above 0.6 m (2 feet).

The maximum liquid depth for the secondary cell(s) of a facultative lagoon shall not exceed 2.1 m (7 feet) unless provisions are made to maintain aerobic conditions in the cell. Storage cells should be operated so that desiccation of the cell floor does not occur due to freezing or drying. Generally a minimum of 0.3 m (1 foot) of liquid should be maintained in the storage cells following discharge. This can normally be accomplished by liquid transfer from the primary cell following discharge.

Consideration should be given to the operational requirement for removal of sludge mounds. Design of influent piping, pads, etc. should facilitate this operation as much as practically possible.

4.4.6 Storage Cells

Operational and environmental considerations may establish the need for storage cells following mechanical treatment plants or lagoons, etc. The aforementioned considerations may also establish the need for storage in addition to that indicated in clause 4.4.5, such as cases for which effluent evaporation will be practiced or where circumstances do not permit effluent discharge and total retention storage may be required.

4.4.7 Aerated Lagoons

Sufficient oxygen shall be introduced to meet the oxygen demand at all points in the lagoon and to maintain a minimum dissolved oxygen level of 2 mg/L at all times in aerated lagoons. Oxygen requirements generally will depend on BOD loading, degree of treatment and the concentration of suspended solids to be maintained. For the development of design parameters, it is recommended that actual experimental data be developed. Raw sewage strength should consider the effects of industrial wastes and any return sludge. Lagoons that use aeration as a means of odour abatement and that provide aeration at rates below that required to maintain 2 mg/L of dissolved oxygen are not considered to be aerated lagoons,

Detention time shall be sufficient to permit desired stabilization. Additional storage volume should be considered for sludge and ice cover. Influent and effluent conduits should be arranged to ensure a uniform flow pattern. Facilities should be included for regulation of discharge. Consideration should be given to the provision of pre-treatment, such as grit removal facilities.

At least two cells shall be provided for system reliability and to provide a satisfactory degree of treatment while one cell is out-of-service for maintenance and/or repairs.

Selection of aeration devices shall be based on reliability of performance and ease of operation and repair. Mechanical agitators should be accessible for repair and maintenance. Suitable facilities should be provided for cleaning submerged aeration tubing. Equipment should be protected from freezing. Consideration should be given to providing emergency power generation to maintain operation of the aerating equipment during extended power outages.

Air blowers should be provided in multiple units and arranged to meet the maximum air demand and/or mixing requirement with the single largest unit out of service. Air piping systems should consider head losses, etc. and be so designed that the aeration devices can function adequately under all predictable operating conditions.

Air filters should be provided in numbers, arrangements and capacities to furnish at all times an air supply sufficiently free from dust to prevent damage to blowers and clogging of the diffuser system used.

Due consideration should be given to the effects of noise on the surrounding environment and provision of winter protection for equipment.

4.4.8 Municipal Lagoon Decommissioning

There are two main methods of decommissioning typical municipal lagoons:

- Desludge and haul
- Landfarm sludge on-site

4.4.8.1 Decommission by Desludge and Haul

For this option, the cells are deslugged and the sludge is hauled to a nearby landfill or an appropriate landfarm location. The sludge should be removed in a frozen state for ease of handling and to minimize odours. Once sludge haul is completed the dykes are leveled and the site may be used for agricultural, commercial, industrial or parkland purposes. Industrial or agricultural lagoons may require more advanced decommissioning methods.

4.4.8.2 Decommission by On-Site Landfarm

For this option, the cells are drained and the sludge is allowed to dry on site. Drying may take considerable time depending on climatic conditions. During this time the dykes must be checked frequently for any breaching to prevent the entry of surface runoff into the lagoons. Once conditions are suitable for machinery access, the sludge should be worked to allow further degradation and aeration of the organic rich sludge. There is no defined requirement to landfarm the material for a set period of time; however the landfarming should continue for a period of at least 2 years. Once landfarming has sufficiently degraded the organic material, the entire site including the dykes can be leveled and used for agricultural, commercial, industrial or parkland purposes.

Industrial or agricultural lagoons may require more advanced decommissioning methods.

Municipalities who plan to use the decommissioned lagoon site for agricultural purposes should follow Land Application of Municipal Sewage Sludge Guidelines, EPB 296 and ensure that the practice is done in a beneficial and environmentally acceptable manner, protecting the environment and human health from adverse effects. If the decommissioned lagoon site is intended for a use other than agricultural use, such as industrial, commercial or parkland land use, the Maximum Acceptable Concentrations (MAC) of metals in soil shall not exceed the criteria specified in Table 2 of the Land Application of Municipal Sewage Sludge Guidelines, EPB 296. A decommissioned lagoon site shall not be used for residential development. If the decommissioned lagoon site is not to be used for any dedicated land use, the site should be properly fenced and signs placed.

4.5 Chemical (Phosphorus Control)

4.5.1 General

Where phosphorus control is undertaken for nutrient removal purposes, the process shall be designed and operated to meet the discharge quality limits approved by the Water Security Agency.

4.5.2 Lagoons

The use of batch chemical treatment in lagoons should consider:

- bench testing arrangements for dosage application guidelines;
- flow control arrangements; and
- sludge deposit and removal needs.

4.5.3 Treatment Plants

It is recommended that laboratory, pilot and/or full scale testing of chemical dosages and application points be carried out to determine the appropriate chemical process. Flexibility for changes in chemical dosages and application points should be considered. Chemical storage, handling and feeding facilities should be based on good safety, operational and engineering practices. Process control monitoring and adjustment features should be incorporated. Special consideration should be given to sludge collection, handling and disposal.

4.6 Effluent Disinfection

Where effluent disinfection is required, methods such as chlorination/dechlorination, UV disinfection and ozonation may be used to reduce microorganisms (cysts, bacteria and viruses) in the wastewater effluent.

Considerations for chlorination include:

- all discharged effluent must have no more than 0.02 mg/L of Total Residual Chlorine (TRC);
- contact chambers should be of the plug-flow type to minimize short circuiting and dead spaces throughout the chamber;
- after thorough mixing with chlorine, a contact time of at least 15 minutes at peak hourly flow should be provided. Longer contact times may be required for effluents with high suspended solids loads;
- chlorination capacity should be sufficient to ensure satisfactory downstream water quality for intended water uses. Preferably, the total and fecal coliform levels on disinfected effluents should not exceed 2500/100 mL and 200/100 mL respectively. Generally, chlorine dosage rates should not exceed 25 mg/L and chlorine residuals at the end of the contact chamber should not exceed 2.5 mg/L nor be less than 0.5 mg/L. If greater dosages are necessary to produce an effective bacteriological kill, consideration should be given to longer contact time and/or improved treatment;
- control features for monitoring and maintaining applicable chlorine dosages should be incorporated;
- gas chlorination facilities should conform to applicable sections of Guidelines for Gas Chlorine Storage and Usage (1999); and
- dechlorination facilities and the ability of these facilities to reliably meet TRC limits.

Ultraviolet disinfection (UV) of wastewater may also be required depending on downstream water uses and to meet a site-specific discharge requirements. The effectiveness of UV disinfection system depends on UV intensity, contact time, the manufacturer, the site, equipment design and materials, the capacity of the plant and the characteristics of the wastewater to be disinfected. The annual operating costs include power consumption, cleaning chemicals and supplies, miscellaneous equipment repairs, replacement of lamps and staffing requirements.

The main components of a UV disinfection system are lamps, a reactor and ballasts. The source of UV radiation is mainly from mercury arc lamps equipped to perform at varying intensities.

Other disinfection methods such as ozonation can also be used in full-scale plants for effluent disinfection. Ozonation is mostly suited to effluents that are highly clarified, nitrified or both. Pilot-scale testing is recommended to determine the design requirements for ozonation system.

The design factors for ozonation systems are:

- selection of a feed gas system;
- selection of the ozone generator;
- ozone dosage;
- design of the ozone contact basin;
- destruction of off-gas ozone; and
- dispersion and mixing of ozone in wastewater.

Ozone must be generated on site because it is chemically unstable and decomposes rapidly to oxygen after generation. The concentration of ozone produced by air is 1.5 to 2.5 per cent by weight. Ozone may be generated from air, oxygen-enriched air or oxygen. The ozone concentration is increased cent if high-purity oxygen is processed by the same low-frequency ozone generators.

4.7 Supplemental Treatment

4.7.1 High Rate Infiltration

The use of high rate or rapid infiltration systems for supplemental treatment of sewage shall be based on adequate studies and assessment that demonstrate its acceptability. Designers must consider means to ensure that, over the long-term, volumes will continue to be disposed at the design rate, and ensure that designs address the ability of the technology to meet all effluent discharge limits over the long-term, including Phosphorus if set as a limit. Designs shall include a method of monitoring discharge quality and monitoring for off-site impacts.

4.7.2 Engineered Wetlands

The use of engineered wetlands for supplemental treatment of sewage should be based on careful considerations of operation and maintenance aspects and the benefits to be achieved.

Sewage treatment by wetlands is shown to be effective in areas with warmer climatic conditions. Many forms of wetlands operate by continuous flow in a shallow horizon. That flow typically may not happen effectively in very cold seasonal climates. Therefore effluent must be retained in a cell then treated by wetland during warmer times of the year. This may add in need for storage cells and a relatively larger wetland because it may operate only 6-8 months per year.

For continuous discharge of wastewater to the environment there may be additional treated wastewater quality limits and requirements such as disinfection. Wetlands established in Saskatchewan have been able to perform only a final effluent polishing function, and do not remove significant amounts of BOD or TSS, though such a wetland could be created.

An *engineered or constructed* wetland has a defined treatment capacity per unit area, has a defined depth of flow, and a defined low exfiltration rate and is a manufactured set of works. In Saskatchewan, frost penetration into soil typically exceeds 2 metres and this can be detrimental to wetland treatment rate, to a lesser extent on the subsurface flow types. Engineered wetlands must be lined or otherwise proven to exhibit no more than 150 mm of exfiltration per years for those areas where final effluent quality limits have not been met.

4.8 Sludge

4.8.1 Process

Process selection should include the following considerations:

- sludge characteristics;
- energy requirements;
- effectiveness of sludge thickening;
- complexity of equipment;
- manpower requirements;
- toxic effects of heavy metals and other substances on sludge stabilization and disposal;
- treatment of side-stream flow such as digester and thickener supernatant;
- odour problems;
- back-up method of sludge handling and disposal; and
- method of ultimate sludge disposal.

4.8.2 Thickening

Sludge thickening (reducing the free water content of sludge) can provide advantages and disadvantages to the overall sludge disposal system. The following lists the main advantages:

- reduction in digester sizing requirements to achieve the same solids retention time;
- reduction in heat exchanger capacity requirements;
- reduction in ultimate disposal costs; and
- reduction in sludge pumping costs.

Excessive reduction of the free water content may have the following disadvantages:

- sludge mixing and blending facilities may be required to combine sludges of differing water content for subsequent treatment operations;
- sludge of high solids concentration is not free flowing and may require special sludge handling equipment; and
- dry sludge may not be as acceptable for spreading on agricultural lands as liquid sludge because of its significant loss of available plant nitrogen content.

In considering the need for sludge thickening facilities, the economics of the overall treatment processes should be evaluated, with and without facilities for sludge water content reduction. This evaluation should consider both capital and operating costs of the various plant components and sludge disposal operations affected.

Sludge thickener design should include consideration of:

- type and concentration of sludge;
- sludge stabilization process;
- method of ultimate sludge disposal;
- chemical needs;
- cost of operation; and
- pumping and piping of the concentrated sludge.

4.8.3 Digestion

Consideration should be given to not only what type of digestion will best suit a particular treatment plant, but also what type of overall system including plant type and digestion type will produce the desired results at least cost. Design, installation, operation and maintenance of digester gas systems should conform to the Canadian Gas Association's "Installation Code for Digester Gas Systems".

Anaerobic digestion systems, often preferred for primary sludge and mixtures of primary and waste activated sludges, should be designed for two-stage digestion. Design parameters based upon the first digester volume only should be as follows:

- volatile solids loading not to exceed $1.6 \text{ kg/m}^3\text{-d}$ ($100 \text{ lbs/1000 ft}^3\text{-d}$);
- minimum hydraulic retention of 15 days;
- temperature be maintained at 35°C ;
- adequate mixing via digester gas or mechanical means; and
- suitable gas withdrawal and gas storage facilities.

The second stage digester should be designed in accordance with design parameters as follows:

- adequate size permitting solids settling for decanting and solids thickening operation; and
- necessary digested sludge storage depending upon the means of ultimate sludge disposal.

Aerobic digestion, involving prolonged aeration of sludge in an open tank that treats waste activated sludge should be designed for two-stage digestion in accordance with the following design parameters. If primary sludge is to be included, minimum sludge age and air requirements may have to be increased.

- volatile solids loading based upon the first stage digester volume only not to exceed $1.6 \text{ kg/m}^3\text{-d}$ ($100 \text{ lb/1000 ft}^3\text{-d}$);
- a minimum sludge age of 45 days including both stages and sludge age of waste activated sludge;
- volume distribution to be $2/3$ of the total volume in the first stage and $1/3$ in the second stage;
- necessary digested sludge storage depending upon the means of ultimate sludge disposal; and
- sufficient air be provided to keep solids in suspension and maintain dissolved oxygen concentration between 1 and 2 mg/L.

4.8.4 Dewatering

Sludge lagooning should be considered for thickening or storage of digested sludge from anaerobic or aerobic digestion process.

The design and location of sludge lagoons should include the following factors:

- possible nuisances - odours, insects, appearance;
- design - number, size, shape, depth, method of decanting supernatant, method of dewatered sludge removal, method of cleaning operation;
- loading factors - solids concentrations of feed sludge, loading rates;
- site conditions - surrounding land use, buffer requirements;
- soil conditions - permeability of soil, need for liner, stability of berm slopes, etc;
- groundwater conditions - maximum groundwater level, direction of groundwater flow, locations of wells in the area;
- climate effects - rainfall, snowfall, evaporation, freezing; and
- costs - capital costs including land cost and operating costs including costs of sidestream treatment and ultimate disposal of dewatered sludge.

Selection of mechanical dewatering equipment should take into consideration the following:

- sludge quantities;

- sludge characteristics;
- sludge pre-treatment requirements;
- sludge conditioning requirements;
- solids concentration of dewatered sludge and its ultimate disposal;
- impact of sidestreams;
- power requirements; and
- costs including capital cost, operation and maintenance costs and costs of the total solids system component for each alternative's operation.

Where possible, pilot-scale testing should be conducted to obtain data for selecting equipment and to predict equipment performance.

4.8.5 Reuse and Disposal

Determination of acceptable sludge disposal practices should be considered an integral part of the total sewage treatment operation.

Sludge disposal by landfilling, agricultural land application and incineration should be carried out in a manner that will prevent a danger to the public health, damage to the environment or creation of a nuisance.

Land application of processed sludge to utilize the beneficial components is encouraged, but should be on a site specific basis with consideration given to sludge quality, winter storage, landowner acceptance, soils characteristics, acceptable crops or vegetation, application boundaries and application rates. Land application of processed sludge should conform to the publication Land Application of Municipal Sewage Sludge Guidelines.

4.9 Effluent Disposal

4.9.1 General

Necessary agreements, attached to the land, shall be obtained for the overland discharge of effluent onto or across private lands prior to finalization of the treatment facility.

Discharge impacts with respect to land use, drainage, flooding and water use should be considered and measures taken in the treatment facility design to minimize adverse impacts.

Where feasible, effluent discharge to any part of recreational lakes or reservoirs or drinking water supply impoundments should be avoided.

No discharge from the lagoon system shall take place due to construction without prior approval from the Water Security Agency. If construction will cause release of any effluent from the existing wastewater system, the permittee must first contact the Water Security Agency and obtain approval.

4.9.2 Receiving Streams

In general the characteristics of receiving streams should be determined using historical data and/or any necessary auxiliary information. Additional information on receiving stream evaluation is in the publication Downstream Use and Impact Studies.

Considerations to minimize effluent impact should include:

- measures to increase dissolved oxygen content;
- outfall location and full or partial submerged dispersion; and
- desirable mixing patterns in terms of instream and downstream uses.

4.9.3 Effluent Irrigation

The use of suitably-treated wastewater for food crops, non-food crops and golf course irrigation is considered an acceptable and sometimes desirable practice, provided the operation is designed and operated to avoid public health and other environmental problems and is agriculturally beneficial. While providing recycling of our valuable water resource, treated wastewaters are an inexpensive water source, contain useful plant nutrients such as nitrogen and phosphorus, and normally will increase crop yields and promote good grass growth on golf courses.

Treated wastewater irrigation is generally considered for one or more of the following:

- to avoid wastewater discharge across privately-owned lands or into intermittent watercourses;
- as an alternative to nutrient or phosphorus removal, where required;
- as an alternative to exceptionally high treatment requirements; and
- to provide a water supply for food crops, non-food crops and golf course irrigation.

4.9.3.1 Design

The irrigation system should be designed based on crop and any leaching requirements. Consideration should be given to avoiding runoff, operating flexibility, the need to 'rest' land, alternate short-term water sources and natural precipitation variations. Minimum effluent treatment and storage requirements are seen in Section 12 of The Waterworks and Sewage Works Regulations.

The chemical, physical and morphological characteristics of a soil must be compatible to irrigation with a particular wastewater. It is important to minimize soil degradation to ensure that lands irrigated with treated wastewater benefit from irrigation and will retain productivity. The soil should not receive harmful quantities of undesirable elements and substances. The physical properties of soil texture and structure are important features when evaluating the use of treated wastewater for irrigation. Careful consideration should be given to permeability, since the suitability of soil for irrigation depends on the ability to conduct air and water. Permeability problems usually occur in top surface of the soil and are mainly related to a relatively high sodium or low calcium content in this zone. Sodium Adsorption Ratio (SAR) and Electrical Conductivity (EC) should be used to evaluate the potential permeability problem. The first significant design step in most irrigation projects is a soil-water compatibility study.

The topography should be suitable, not only for the irrigation procedure, but also to minimize runoff from the irrigation site.

Pump suctions or other irrigation intake works in the storage cells should be located as far as possible from the influent to prevent short circuiting of the effluent. Effluent with a significant component of industrial wastewater requires individual design considerations.

Irrigation sites should be located to avoid spray drift on roads, recreational areas and private lands and impacts to features such as wells. A proposed irrigation project with a design sewage flow of 455 m³/day (one million gallons/day) or more will require a hydrogeological investigation based on irrigated volumes and long-term effects on soil and groundwater. An assessment of long-term soil and groundwater effects will be required. The water table in the irrigation area must be sufficiently deep to prevent water table rise to the root of the plants. Use of land for wastewater irrigation overlying shallow aquifers utilized for water supplies must be avoided.

The Water Security Agency's review of wastewater effluent irrigation works focuses mainly on the quality of wastewater used for irrigation and protection of public health and environment. Project proponents are strongly advised to contact agrologists to determine the long-term sustainability of soil productivity for agricultural purposes.

Ownership of lands to be irrigated should be obtained in the case of all new effluent irrigation projects. It is highly recommended that the owners of wastewater systems employing effluent irrigation in operation or beyond a pre-design stage as of April 1, 2004 seek ownership of any lands to be irrigated. In the case of existing effluent irrigation works where land ownership cannot be obtained, an easement agreement between the proponent of the wastewater facility and landowners with a minimum term of 10 years is preferred. Provision should be made in the agreement for general liability, liability for any future soil related problems, operating procedures/restrictions, monitoring and other responsibilities as deemed appropriate by the circumstances of the project.

Groundwater and soil monitoring will be required for wastewater irrigation projects the extent of which will depend upon size and groundwater resources. If disposal by irrigation is proposed, then a contingency plan should be developed to dispose of at least 50% of design volumes by other means. The contingency plan will not be approved as part of the new works approval. If the contingency plan is required to be used after construction of the new works then it must be approved at that time.

To ensure effective long-term operation with no damage to lands, owners shall provide a sustainability report to the Water Security Agency every eight years or as stipulated in the Permit to Operate. The report will

include presentation and assessment of monitoring results for the last eight years, a review of crop records and soil and water monitoring results to determine agricultural sustainability of the works, presentation of any complaints received by the owner and presentation of any known off-site impacts. Effluent irrigation systems determined not to be agriculturally sustainable or displaying off-site impacts may have Permit to Operate conditions altered.

Additional design information is available in publication Treated Municipal Wastewater Irrigation Guidelines.

4.9.4 Evaporation and Other Disposal Options

Other disposal options may include exfiltration or evaporation. Exfiltration system designs shall include evaluation of impacts to groundwater, movement of the effluent plume, salinization of land and impacts on water wells and any other known local use. Exfiltration projects must have rigorous controls and significant monitoring to prevent contamination. Exfiltration projects must include a plan to track the plume and must provide a report each five years on plume location complete with a projection of the location and extent of the plume in the next year and in ten years. Proposing use of exfiltration must consider costs associated with such studies. A plan must be developed to ensure exfiltrated volumes can reliably and safely be disposed of in the long term. This plan must include monitoring of groundwater uses that may be impacted by the exfiltration proposal.

If disposal by evaporation is planned, the design should include a minimum contingency of 30% for cell evaporation areas less than 5 ha and a minimum 25% contingency for cell areas equal or greater than 5 ha. Evaporation designs must not include the treatment portion (i.e. the primary cell) of the works as evaporation area. As with the design of a typical secondary lagoon cell, the seepage rate shall not be included in the disposed volume calculation. Evaporation cells are to be engineered and lined cells. Small evaporation facilities may be designed based on study of mean annual net evaporation; evaporation facilities exceeding 25 ha must have a long-term net evaporation model undertaken in which hydrology information such as precipitation and evaporation needs to be assessed. All evaporation designs must include a plan to accommodate the potentially low volume of high-salt high-evaporite effluent that may be retained after many years of operation.

If disposal by exfiltration or evaporation is proposed, a contingency plan is required to dispose of at least 50% of design volumes by other means. The contingency plan will not be approved as part of the new works approval. If the contingency plan is required to be used after construction of the new works then it must be approved at that time.

Wastewater facilities that allow sewage haulers to deposit liquid at exfiltration, evaporation, irrigation and regular lagoon facilities are recommended to have controls on access of haulers to ensure the facility is not receiving waste volumes greater than the design allows. Frequent requests for temporary approval to allow volumes to be transferred out of evaporation or exfiltration cells will not be approved, and facilities may be required to stop receiving new loads until liquid levels in cells have returned to acceptable levels.

5. Storm Drainage

5.1 General

Storm sewer design should be carried out in accordance with all local bylaws and policies. Under *The Environmental Management and Protection Act, 2010 (EMPA)* and *The Waterworks and Sewage Works Regulations*, stormwater quality and its management is not specifically regulated other than a requirement for no interconnection between sanitary and storm sewers as seen in Section 7 of *The Waterworks and Sewage Works Regulations*.

The Water Security Agency publication Stormwater Guidelines provides high-level technical guidance to municipal authorities, individuals and consultants who plan to develop and implement drainage systems for stormwater in urban/built-up municipal areas, commercial and industrial areas in Saskatchewan. Although the guidelines provide technical and practical guidance, users must exercise judgment in planning, designing and implementing stormwater management works.

Stormwater management solutions are site specific. The designer should determine if a single practice or a combination of practices are needed to meet the stormwater objectives and goals for any given site and is responsible for the design and decisions made with respect to stormwater management.

Voluntary use of the Stormwater Guidelines will aid minimizing the impacts on receiving waters due to stormwater discharges and may serve as a diligent approach to improved stormwater management in the province.

Glossary of Symbols and Abbreviations

Sewage Works Abbreviations

ASTM	American Society for Testing and Materials
AWWA	American Water Works Association
CGSB	Canadian General Standards Board
CSA	Canadian Standards Association
$^{\circ}\text{C}$	degree Celsius
ft	feet
fps	feet per second
gcd	gallons per capita per day
$\text{g/ft}^2\text{-d}$	gallons per square foot per day
gpd	gallons per day
gpm	gallons per minute
ha	hectare
IDF	Intensity/Duration/Frequency
in	inch
kg/ha-day	kilograms per hectare per day
$\text{kg/m}^2\text{-hr}$	kilograms per square metre per hour
$\text{kg/100 m}^3\text{-d}$	kilograms per one hundred cubic metres per day
$\text{kg/m}^3\text{-d}$	kilograms per cubic metre per day
km	kilometre
lb/acre/day	pounds per acre per day

Sewage Works Abbreviations

lbs/capita-day	pounds per capita per day
$\text{lb/ft}^2\text{-hr}$	pounds per square feet per hour
$\text{lbs/1000 ft}^3\text{-d}$	pounds per one thousand cubic feet per day
L/s	litres per second
m	metre
mg/L	milligrams per litre
mm	millimetre
$\text{m}^3/\text{m}^2\text{-d}$	cubic metres per square metres per day
m/s	metres per second
NPSH	Net Positive Suction Head
RBC	rotating biological contactor

Recommended Metric Units

Air supply (filter wash)	- $\text{m}^3/\text{m}^2\text{-h}$	cubic metres per square metre of filter area per hour
	- m/h	metres per hour
Area	- m^2	square metres
	- ha	hectare (lagoons)
Concentration	- mg/L	milligrams per litre (dilute)
	- %	percent (concentrated e.g. sludge)
Detention time	- minutes (short)	
	- hours (long)	
Distance	- km	kilometres
Design capacity	- m^3/d	cubic metres per day
Filter media depths	- mm	millimetres
Filter wash quantity	- m^3/m^2	cubic metres per square metre of filter area
Filter wash rate	- m/h	metres per hour (equiv. $\text{m}^3/\text{m}^2\text{-h}$)
Filtration rate	- m/h	metres per hour (equiv. $\text{m}^3/\text{m}^2\text{-h}$)
Flow rate	- L/s	litres per second
Organic loading	- kg/ha-d	kilograms per hectares per day (lagoons)
	- $\text{kg/100m}^3\text{-d}$	kilograms per one hundred cubic metres per day (lagoons)

	- kg/m ² -hr	kilograms per square metre per hour (biological sedimentation)
	- kg/m ³ -d	Equivalent to 100 lb/1000 ft ³ -d kilograms per cubic metres per day (digesters)
Per capita flow	- L/cap-d	litres per capita per day
Pipe size	- mm	millimetres
Power	- kW	kilowatt
Pressure	- kPa	kilopascal (positive)
	- mm Hg	millimetres of mercury (negative)
Surface overflow rate	- m/h	metres per hour (equiv. m ³ /m ² -h)
	- m/d	metres per day (equiv. m ³ /m ² -d) (sewage)
Solids loading	- kg/h	kilograms per hour (sludge treatment)
Temperature	- °C	degrees Celsius
Underflow velocity	- m/min	metres per minute
velocity	- m/s	metres per second
	- m/min	metres per minute (settling)
Volume	- litres (small)	
	- Gallon	- 4.546 L (Imperial)
	- m ³	cubic metre (large)
Weir overflow	- m/hr	metres per hour (equiv. m ³ /m ² -hr)