Guidelines for Sewage Works Design

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Foreword

This document replaces A Guide to Sewage Works Design published by Saskatchewan Environment and Resource Management; March, 1996.

Except for industrial wastewater works, the design guide applies to all sewage works described in the *The Water Regulations,* 2002 and should 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*, 2002:
- *The Water Regulations,* 2002;
- Surface Water Quality Objectives, 1997; and
- Guidelines for Chlorine Gas Use in Water and Wastewater Treatment, 1999.

The design of a sewage works should:

- 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.

The design guide is not intended to be a detailed engineering manual. Innovative or alternate approaches with demonstrated benefits should be utilized to protect both public health and the environment.

Please forward inquiries concerning the guidelines to:

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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 Saskatchewan Environment before starting construction of such works. Applications for approval are required to be made on prescribed forms obtained from Environment.

Typical examples of works requiring construction approvals include:

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

Applications for approvals are required to contain information prescribed in section 1.2. Information should be in a concise form and a logical order. Drawings and plans should 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.

Municipalities and other sewage works owners are advised that First Nations and Métis Consultation must take place before any lagoon or mechanical treatment works construction, upgrading or decommissioning activities that could adversely affect Treaty or Aboriginal rights is developed or put in place. Although the need for notification or consultation will depend on the specific circumstances of construction, upgrading or decommissioning, such consultation is to begin at the earliest possible time (conceptual stage) and to some degree could involve the municipalities or other sewage works owners and their consultants. For more information, the Government of Saskatchewan Guidelines for Consultation with First Nations and Métis People: A Guide for Decision Makers (http://www.fnmr.gov.sk.ca/documents/policy/consultguide.pdf) is available on the internet. Municipalities and other sewage works owners are also advised that such construction, upgrading or decommissioning activities with a significant areal impact will need to have an initial review called a Heritage Resource Review or HRR which will determine if a broader Heritage Resource Impact Assessment or HRIA is necessary.

1.2 Information on Application for Permit

1.2.1 General

When a person makes an application for a permit to do those things described in section 22 of the Act, 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; and
- cost estimates for the work including applicable local improvement or capital portions;
- if applicable, application for permit shall include easement agreement containing the following information and provisions:
  - a) the name of the person proposing to construct, extend, alter or operate the 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 that is the subject of the easement;
    - ii) conveys a right to use the land for the purposes and to the extent required to construct, alter, extend or operate the 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 waterworks 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 kilometre 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 kilometre 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.

For effluent irrigation projects, the following information should also be provided:

- 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 irrigation agreement, if applicable.

2. Sanitary Sewers

2.1 General

2.1.1 General Aspects

Design and construction of sanitary sewers should 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

In general, sewer capacities should be designed for the estimated tributary population to be ultimately served, except in considering parts of the systems that can be readily increased in capacity. Similarly, consideration should be given to the maximum anticipated capacity of institutions, industrial parks, etc.

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.

2.1.3 Waterworks Protection

There should be no physical connection between a public or private potable water supply system and a sewer or appurtenance thereto, which could permit the passage of any sewage or polluted water into the water supply.

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

Adequate separation of water mains and sewers should be maintained with due consideration given to such matters as pipe materials; soil conditions; service connections into the mains; etc. Water and sewer mains should be installed as per section 26 (1,2,3, & 4) of *The Water Regulations, 2002*.

2.2 Gravity Collection System

2.2.1 Hydraulic Design

Sanitary sewers should 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, etc., should be considered. It is recommended that no gravity sewer conveying raw sewage should be less than 200 mm (8 inches) in diameter.

Sanitary sewers should 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.

Velocities in sanitary sewers should be limited to no more than 3 m/s (10 fps), especially where high grit loads are expected. If higher velocities are unavoidable, special precautions should be taken to protect against displacement and pipe erosion.

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.

2.2.2 System Layout

Sanitary sewers should be located in accordance with all applicable local standards. In general, sewers should be located at or near the centre line of streets/roads to allow servicing to both sides and should 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 should be given to reduce manhole spacing, increased grades and other generally recognized techniques which permit curved sewers to function satisfactorily.

In general, sewers should be sufficiently deep to be protected from external loading damage, to receive sewage from basements and to prevent freezing. Insulation should be provided for sewers that cannot be placed at sufficient depth to prevent freezing.

Sewers which either cross or run parallel to watercourses or other such features should be given special attention. Aerial crossings should be avoided, if possible. Inverted syphons, if required, should have not less than 2 barrels, with a minimum size of 150 mm (6 inches) and should be provided with necessary appurtenances for convenient flushing and maintenance. The manholes should have adequate clearances for rodding; and in general, sufficient head should be provided and pipe sizes selected to secure velocities of at least 1 m/s (3.3 fps) for average flows. The inlet and outlet details should be arranged so that normal flow may be diverted to one barrel when the other barrel is out of service for cleaning. The vertical alignment should permit cleaning and maintenance.

2.2.3 Materials/Construction

Sewer pipe, manholes, and sewer appurtenances should comply with appropriate CSA, ASTM or CGSB standards. Pipe selection should consider local conditions such as character of industrial wastes, possibility of septicity, soil characteristics, exceptionally high external loadings, abrasion and similar problems.

Sewers should be designed to prevent damage from superimposed loads. Proper allowance for loads on sewers should consider type of pipe, width and depth of trench and the need for special bedding, concrete cradles or other special construction techniques.

Sewer joints should 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 should provide stability and generally conform to the pipe manufacturer's recommendations.

2.2.4 Manholes

Manholes should be installed at the end of each line, and at all changes in grade, size or alignment. Manhole spacing should not exceed 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.

The manholes should be designed to be watertight, durable and of adequate size for ease of entry and maintenance. Minimum diameter should be 1050 mm (42 inches). Bases should be watertight and "flow-through" channels through manholes should be made to conform in shape and slope to that of the sewers.

Wherever manhole tops may be flooded by street runoff or high water, watertight manhole covers should be used. Consideration may be given to providing suspended baskets to catch debris that may enter manholes, such as gravel from unpaved streets.

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. Where the difference in elevation between the incoming sewer and the manhole invert is less than 600 mm (2 feet), the invert should be filleted to prevent solids deposition.

2.3 Pressure System

Pressure systems (sometimes referred to as "Modified Sewage Works"), where individual contributors pump partially treated sewage into a public pressure main, may be considered for small installations where topographical and 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 design should consider pressure limitations of joints, tees, fittings, etc. Backflow preventors should be installed on all service lines and a sufficient number of isolation/shut-off valves should be provided to minimize inconvenience during service repairs.

All valves, piping, fittings, appurtenances should be of high quality durable material, capable of withstanding service pressures and conforming to applicable CSA, AWWA, ASTM or CGSB standards. Piping should be installed at an adequate depth to prevent freezing and/or damage from other activities.
In all other respects, design of Modified Sewage Works should ensure that all environmental and/or health conditions will be safeguarded.

2.4 Special (Innovative) Systems

Gravity collection systems are generally preferable because of dependability, but where gravity systems are not feasible, consideration may be given to innovative systems. Design of such systems should take into consideration such factors as training and background of proposed operating personnel to assure that the system will function satisfactorily. In all respects, design of such systems should ensure that all environmental and/or health conditions can be safeguarded.

3. Sewage Pumping Stations

3.1 General

3.1.1 Location

Sewage pumping station structures and electrical/mechanical equipment should be protected from physical damage and should remain fully operational during floods.

During preliminary location planning, consideration should 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 should 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 should 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 should be made for provision of well documented and durably bound operation/maintenance manuals. The manuals should contain:

- 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 should be provided to dry wells and to wet wells requiring maintenance or inspection. Stairways are preferable to ladders. All ladders, side rails, handrails, platforms, etc. are to be in accordance with applicable occupational health and safety legislation and regulations. Adequate lighting must be provided.

For the design and installation of all electrical equipment, lighting, wiring, etc. and all gas-fired heating equipment, reference should be made to applicable codes, legislation and approval requirements. Care should be taken to ensure the avoidance of any cross connections with any potable water supplies or contamination of potable water.

3.2 Structures

3.2.1 Wet Wells

Wet well capacity should 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.

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 should 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 wastes is required, a separate manhole complete with screening protection where required, should be considered.

Where condensation may cause access or corrosion problems at the top of wet wells, consideration should be given to providing heating 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 should provide stability, durability, structural integrity and water-tightness.

3.2.2 Dry Wells

Due consideration should 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 should be provided as required for operating ease and to prevent potential freezing problems due to condensation.

Dry well structures should 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 Equipment

Due consideration should 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.

3.2.4 Ventilation

Permanent ventilation should be provided for all sewage pumping stations with no interconnection between the wet well and dry well ventilation system. The following minimum air change rates are recommended to provide adequate ventilation:

- wet wells - continuous ventilation - 12 changes/hour;
- intermittent ventilation - 30 changes/hour;
- dry wells - continuous ventilation - 6 changes/hour; and
- intermittent ventilation - 30 changes/hour.

Switches for the operation of ventilation equipment should 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.

Ventilation should be by mechanical means. 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 should 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.

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

3.3 Pumps

3.3.1 Units/Capacity

Pump capacities should 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 should 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, they should be designed to fit actual flow conditions and should be of such capacity that with any 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 should 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 which consider the size of the station, the degree of protection required, overflow provisions, availability of operation and emergency personnel, etc., should be incorporated into the design of pumping stations.

Due consideration should be given to providing corrosion protection of all piping/control elements. Flow measurement devices should be considered for all stations and particularly for main sewage pumping stations.

3.4 Emergency Operation

Pumping stations (and collection systems) should be designed to prevent by-passing of raw sewage. For use during possible periods of extensive power outages or uncontrolled storm events, consideration should 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. Where a high level overflow is necessary, consideration should also be given to the installation of storage/detention tanks or basins which can drain back to the wet well following the emergency.

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 should take into consideration accessibility for operation, maintenance and ease of repair during emergency situations. Valves, air release valves and flushouts should 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 should be fitted with a valve prior to entering the lagoon.

Force mains should 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 should be constructed of suitable durable materials conforming to applicable CSA, AWWA, ASTM, or CGSB standards. Force mains and fittings, including reaction blocking, should be designed to withstand normal pressure and pressure surges (water hammer).

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 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 should be positioned at proper points in the forcemain to prevent hydraulic problems. Forcemains should be graded to facilitate placement of valves, flushouts and appurtenances.

4. Sewage Treatment

4.1 General

4.1.1 Approvals

During the investigation for sewage treatment facilities, the requirements of other administrative authorities with respect to environmental impact assessments, zoning, planning, land use, etc. should be reviewed and applicable consultation undertaken. As well, the effect on potentially impacted landowners should 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 should be obtained which defines rights and responsibilities.

4.1.2 Process Selection

A process should 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 should be given to:

- 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.

Table 4.1 Sewage Treatment Processes – Typical Effluent Quality

Process	BOD_5 mg/L	TSS mg/L	Total P mg/L	Total N mg/L	Total Coliforms/ 100 mL
Primary					
(incl. anaerobic lagoons)	75-150	50-110	5-7	25-45	>2x10^6
with phosphorus removal	45-85	25-50	1-2	20-40	>2x10^5
Secondary					
Biological (Mech.)	10-25	10-25	3.5-6.5	15-35	2x10^4-2x10^5
Aerated Lagoons	15-30	20-35	4-7	20-40	2x10^3-2x10^5
Facultative Lagoons					
- Spring	25-70	20-60	3.5-7	20-35	<2x10^3-2x10^5
- Late Fall	10-30	10-40	2-5	5-20	2x10^2-2x10^4
Advanced					
Secondary with chemical treatment (phosphorus control)	5-15	10-30	0.5-1.5	15-35	2x10^2-2x10^4

4.1.4 Location

Siting considerations should 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.

In general, sewage treatment facilities should be located to avoid local objections and as far as possible from existing or pending development. Mechanical sewage treatment plants should be located at least 300 m (1,000 ft) from developments, particularly from those of a residential, commercial or institutional nature. Lagoon siting considerations are contained in Section 4.4.2.

4.1.5 Design Loading

The treatment facility should 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 BOD_5 for raw sewage from domestic, commercial, and light industrial sources of 77 grams/capita-day (0.17 lbs/capita-day) may be considered.

4.1.6 Plant Facilities

For the design and installation of sewage treatment components and building services, reference should be made to applicable codes, legislation and approval requirements. Plant design should incorporate safety features relevant to the process and as may be required by administrative authorities. Plant building design should incorporate space for 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, 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. Care should be taken to ensure no potential cross connections exist.
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 should 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 colouring 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 4.1.

Table 4.1 Wastewater Treatment Plant Piping – Recommended Colour Code

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

Notes:

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

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 m^3/m^2-d (1400 g/ft^2-d) for tanks not followed by secondary treatment;
- 35 m^3/m^2-d (700 g/ft^2-d) with phosphorous removal using alum or ferric compounds;
- 45 m^3/m^2-d (900 g/ft^2-d) with phosphorus removal using lime;
- 50 m^3/m^2-d (1000 g/ft^2-d) for tanks followed by secondary treatment with waste activated sludge handling in the tanks; and
- 80 m^3/m^2-d (1600 g/ft^2-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. 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;
- 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:ruggedness of construction;

- ease of cleaning;
- 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;
- 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 m^3/m^2-d (1000 g/ft^2-d) or 10 kg/m^2-hr (2 lb/ft^2-hr) for activated sludge with no chemical addition to mixed liquor for phosphorus removal;
- 35 m^3/m^2-d (700 g/ft^2-d) or 10 kg/m^2-hr (2 lb/ft^2-hr) for activated sludge with chemical addition to mixed liquor for phosphorus removal;
- 30 m^3/m^2-d (600 g/ft^2-d) or 5 kg/m^2/hr (1 lb/ft^2-hr) for activated sludge with nitrification process; and
- 35 m^3/m^2-d (700 g/ft^2-d) or 5 kg/m^2-hr (1 lb/ft^2-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 facultative lagoons and/or aerated lagoons.

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.

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 should consider a wide range of pertinent factors such as 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.

Lagoons should be located at least 0.3 km (1,000 feet) from isolated human inhabitation and 0.6 km (2,000 feet) from built-up areas, if possible, with consideration given to the direction of prevailing spring winds and potential future municipal expansion.

Greater isolation distances should be considered, if feasible, for waste stabilization ponds which are not of the aerated lagoon type. Lesser isolation distances may be considered for private lagoons with respect to the owners' buildings. Applicable isolation distances required by road, highway and railway authorities should 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 should consider applicable shoreline regulations that may currently be in effect.

In determining land requirements, due consideration should 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 should be undertaken to establish the suitability of proposed materials to meet anticipated conditions. Generally a minimum of 3 test holes per site or 1 test hole per 2 hectares (whichever is greater) should 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 should be dug to at least 4 metres below 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 and monitor well requirements and locations if these are required.

Lagoon cells should be relatively impermeable in accordance with the needs for functional treatment and protection of surrounding land and ground water. As an example, seepage from a lagoon facility should be limited to 15 cm per year. Greater seepage losses may be permitted if it can be demonstrated that surrounding land and groundwater will not be adversely affected or other suitable provisions are made to intercept the seepage. It is recommended 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. At least one hydraulic conductivity test per 2 hectares of lagoon area should be carried out. For in-situ materials or soil liners an on-site permeability of 10 times the laboratory value should be used to calculate seepage losses. Adequate provisions for monitoring and for seepage control measures such as cutoffs, sub-surface drainage interceptors, etc. should 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 should 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.

The complete waste stabilization pond area should be enclosed with an adequate fence to prevent entering of 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 advise 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.

Dykes should be constructed so the top width should be at least 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 should be a minimum of 1 m (3 feet) except for very small systems where 0.6 m (2 feet) may be considered.

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 .15 m (6 inches) above the design operating level of the lagoon.

Pressure mains terminating in a sewage lagoon should 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.

Where practical, consideration should be given to provision of flow measurement and sampling devices.

4.4.4 Facultative Lagoons

At least 2 cells, operating in series, should be provided. Additional cells may be required and the design may include facilities for series and parallel operation for operational flexibility.

Except as noted below, the primary (treatment) cell(s) design should be based on a maximum design BOD_5 loading of 30 kg/ha-d (27 lb/acre/day) to effect open water stabilization and minimize odour emission after ice breakup.

The second or subsequent cells should have sufficient volume to provide a minimum of 180 days storage, based on hydraulic loading including infiltration and inflow with due allowances for potential evaporation and exfiltration losses. Special consideration should be given to the discharge arrangements and the need for increased storage.

For small summer-type operations, for which 75 per cent of the sewage flow occurs from May to September, the primary cell may be sized on the basis of BOD_5 loading of 55 kg/ha-d (49 lb/acre/day), with the design derived from the average loading for a maximum week. The second cell should have sufficient volume to contain the annual flow.

The liquid depth for primary (treatment) cell(s) at design operating stage should 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 0.6 m (2 feet).

The maximum liquid depth for secondary cell(s) should not exceed 7 feet unless provisions are made to maintain aerobic conditions in the cell during the ice free period. 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 and design of influent piping, pads, etc. should facilitate this operation as much as practically possible.

4.4.5 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 4.4.4, such as cases for which effluent irrigation will be practiced or where circumstances do not permit effluent discharge and total retention storage may be required. Effluent irrigation requirements are described in Section 4.9.3.

Storage provided in cases where effluent discharge is impractical or undesirable (ie: evaporation ponds) should take into account infiltration plus exfiltration and net evaporation losses during typical years and have provisions for the occasional "wet" year.

4.4.6 Aerated Lagoons

Sufficient oxygen should 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. 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.

Detention time should 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 should 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 should 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.

4.4.7 Municipal Lagoon Decommissioning

There are two main methods of decommissioning typical municipal lagoons:

- Desludge and haul
- Landfarm sludge on-site

<u>Industrial or agricultural lagoons may require more advanced decommissioning methods.</u>

4.4.7.1 Decommission by Desludge and Haul

For this option, the cells are desludged and the sludge hauled to a nearby landfill or an appropriate landfarm location. The sludge would best 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. Reuse of the lagoon site for residential housing is not recommended.

4.4.7.2 Decommission by On-Site Landfarm

For this option, the cells are drained and the sludge allowed to dry. 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 Saskatchewan Environment would recommend that the landfarming continue for a period of 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. Reuse of the lagoon site for residential housing is not recommended.

Municipalities who plan to use the decommissioned lagoon site for agricultural purposes should follow <u>Land Application of Municipal Sewage Sludge Guidelines, EPB 296</u> 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 or commercial or parkland land use, the Maximum Acceptable Concentrations (MAC) of metals in soil shall not exceed the criteria specified in Table2 of the <u>Land application of Municipal Sewage Sludge Guidelines, EPB 296</u>. Saskatchewan Environment does not recommend using the decommissioned lagoon site 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 should be designed and operated to meet an effluent objective of 1 mg/L as total phosphorus or to conform to any required mass loading limitation.

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 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, UV disinfection and ozonation may be used to reduce microorganisms (cysts, bacteria and viruses) in the wastewater effluent.

Considerations for chlorination include:

- 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
- potential future installation of dechlorination facilities.

Ultraviolet disinfection (UV) of wastewater may also be required depending on downstream water uses and to meet a site-specific discharge requirements, it is recognized that cost can be a major factor in the selection of a suitable UV disinfection system. The cost of UV disinfection system depends on the manufacturer, the site, 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 mercury arc lamps, a reactor and ballasts. The source of UV radiation is mainly from the low-pressure or medium-pressure mercury arc lamp equipped with low or high intensities. Medium-pressure lamps are generally used for large facilities. They have approximately 15 to 20 times the germicidal UV intensity of low-pressure lamps. However, these lamps operate at higher temperatures with a high energy consumption. The effectiveness of a UV disinfection system depends on the characteristics of the wastewater, the intensity of UV radiation, the amount of time the microorganisms are exposed to the radiation and the reactor configuration.

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 to 3 to 5 per 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 should be based on adequate studies and assessment that demonstrate its acceptability.

4.7.2 Aquatic Vegetation

The use of engineered aquatic vegetation basins (emergent macrophytes) for supplemental treatment of sewage should be based on careful considerations of operation and maintenance aspects and the benefits to be achieved.

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 pumpage 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 kg/m^3-d (100 lbs/1000 ft^3-d);
- minimum hydraulic retention of 15 days;
- temperature be maintained at 35^oC;
- 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 kg/m^3-d (100 lb/1000 ft^3-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 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.

4.9 Effluent Disposal

4.9.1 General

Necessary agreements, preferably attached to the land, should be obtained for the 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 recreational lakes or reservoirs or drinking water supply impoundments should be avoided.

4.9.2 Receiving Streams

In general the characteristics of receiving streams should be determined using historical data and/or any necessary auxiliary information.

For continuous flowing streams, effluent impact on receiving water quality should be based on the minimum 7 day consecutive stream discharge that may recur once in 10 years.
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

Proper irrigation using suitably treated wastewaters can be of benefit and generally should be encouraged.

The use of suitably-treated sewage effluents for crop irrigation is considered an acceptable and sometimes desirable practice, provided the operation is designed and operated to avoid public health and other environmental problems.

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

- to avoid effluent 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 to a nearby owner for irrigation purposes. Forage production, tree nurseries or other applications where a low public health risk is involved are acceptable.

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.
Disinfection of the effluent is not normally required. However, effluent should receive at least a secondary degree treatment before using it for irrigation. Storage capabilities (e.g. secondary lagoon cells) should be in the order of 210-230 days sewage flow. 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. If a remote storage is necessary, it should be located at least 1,000 feet from any residences or public places. Industrial wastewater effluents require individual considerations.

The chemical and physical characteristics of the soil should be amenable to irrigation with the particular effluent, to prevent adverse structural changes, salt buildup or other long-term deterioration. The topography should be suitable, not only for the irrigation procedure, but also to minimize runoff from the irrigation site.

The water table should be sufficiently deep to prevent table rise to the root zone. Use on land overlying shallow aquifers utilized for water tables should be avoided.

Irrigation sites should be located to avoid spray drift on roads, recreational areas and private lands and generally should be at least 300 feet from habitation or wells. Appropriate agreements of a minimum 10 year term should be made between owners of the wastewater treatment facility and the irrigated land. Provision should be made for liability, use restrictions, monitoring and conformance to operating requirements. A proposed irrigation project with a design sewage flow of one million gallons/day or more will require a hyrdrogeological investigation and an assessment of long-term soil and groundwater effects.

4.9.4 Other Disposal Options

Other disposal options may include exfiltration or evaporation. Before deciding on an exfiltration system impacts to groundwater, movement of the effluent plume, salinization of land and impacts on water wells needs to be assessed. If disposal by evaporation is planned, hydrology information on such things as precipitation and evaporation needs to be assessed.

5. Storm Drainage

5.1 General

Storm sewers should be designed to convey runoff from rainfall and snowmelt. Storm sewer design should be carried out in accordance with all local bylaws and policies.

Peak storm drainage design flows should be based on runoff computations using Intensity/Duration/Frequency (IDF) data, appropriate runoff coefficients for various parts of the tributary area and generally accepted formulae, such as the Rational Formula. For systems using large areas or involving treatment and/or storage systems, consideration should be given to calculations based on hydrologic simulation modelling.

In the design of storm drainage systems, due consideration should be given to minimizing adverse effects of storm runoff. Efforts to reduce storm runoff from a developed municipal area to that equal to natural flows from the same area before it was developed are encouraged. In this regard, it is recommended that the objectives and/or requirements of all local, regional or provincial jurisdictions be considered in the design phase.

It is recommended that the applicability of using the "major/minor" drainage system approach be considered. By this approach, the minor or piped storm conveyance system provides at least the protection necessary to reduce the inconvenience of storm water ponding during relatively frequent storm events to an acceptable level within the service area. The major system or combination of piped systems, channels, retention or detention basins, roadways and overland flow routes, provides the protection necessary to convey the runoff from less frequent, more intense storm events.

Except for special circumstances, storm sewers should not discharge into sanitary sewers. Special attention should be paid to avoidance of cross connections. Potential industrial or other pollutant discharges should be identified so that their entry into the storm sewage works can be prevented.

5.2 Piping/Appurtenances

Design and construction of piping, manholes, catch basins and all other appurtenances should conform to applicable CSA, ASTM, or CGSB standards and generally accepted industry standards.
Due consideration should be given to such factors as minimum and maximum velocities, ease of maintenance, etc. in the design of storm sewers. As a general guide the minimum design velocity should be 0.9 m/s (3 fps).

Generally manhole spacing should not exceed approximately 150 m (500 feet) for sewers up to 750 mm (30 inches) in diameter. Curved alignment should be avoided for sewers less than 450 mm (18 inches) in diameter.

5.3 Storm Channels, Retention Basins

Where possible, open storm channels should be designed to minimize standing water during dry weather conditions in order to reduce aquatic vegetation growth, mosquito breeding and odour potential.

For the design and utilization of storm water retention basins, particularly if the basins are to serve for aesthetic or recreational purposes, consideration should be given to the maintenance of suitable water quality including the control of algae, weeds or other aquatic nuisances.

5.4 Outfalls

Location of outfalls should include considerations of the impact on downstream users.

Outfall structure design and construction should include consideration of:

- prevention of erosion;
- screening or fencing to prevent unauthorized entry;
- potential spill containment measures; and
- means for flow measurement and water quality sampling.

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
^{o}C	degree Celsius
ft	feet
fps	feet per second
gcd	gallons per capita per day
g/ft^2-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
kg/m^2-hr	kilograms per square metre per hour
kg/100 m^3-d	kilograms per one hundred cubic metres per day
kg/m^3-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
lb/ft²-hr	pounds per square feet per hour
lbs/1000 ft^3-d	pounds per one thousand cubic feet per day
L/s	litres per second
m	metre
mg/L	milligrams per litre
mm	millimetre
m^3/m²-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)	- m^3/m²-h	cubic metres per square metre of filter area per hour
	- m/h	metres per hour
Area	- m²	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/m²	cubic metres per square metre of filter area
Filter wash rate	- m/h	metres per hour (equiv. m^3/m²-h)
Filtration rate	- m/h	metres per hour (equiv. m^3/m²-h)
Flow rate	- L/s	litres per second
Organic loading	- kg/ha-d	kilograms per hectares per day (lagoons)
	- kg/100m^3-d	kilograms per one hundred cubic metres per day (lagoons)
	- kg/m²-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/m²-h)
	- m/d	metres per day (equiv. m^3/m²-d) (sewage)
Solids loading	- kg/h	kilograms per hour (sludge treatment)
Temperature	- ^oC	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/m²-hr)