LLOYDMINSTER

# MUNICIPAL DEVELOPMENT STANDARDS

## SECTION 5 – STORM DRAINAGE SYSTEMS

**October 2020**

Planning & Engineering

# TABLE OF CONTENTS

# 5 STORM DRAINAGE SYSTEMS

## 5.1 General

This Section covers the minimum requirements and standards for storm drainage systems. The design of these systems is to be in accordance with the City of Lloydminster Storm Drainage Master Plan. Drawings relating to the construction of the storm drainage system, trenching and backfilling are provided in the Municipal Development Standard Drawings, sections 3 (Manholes), 4 (Trench and Backfill), 5 (Storm Drainage) and 7 (Service Connections).

### 5.1.1 Objectives

For each storm drainage system, development must be designed for the proposed land use and the ultimate drainage basin, and will be dependent on the type of development, the drainage area and the length of surface drainage runs. In general, development areas must have a design maximum release rate of 1.5 litres per second per hectare (L/s/ha) under the 1:5 year design storm, unless surface modelling indicates a lower release rate in the pre-development condition. Storm water quality discharged from the development must be in conformance with the parameters and guidelines set forth in the City of Lloydminster's Sewer Use Bylaw, and as such erosion and sedimentation control measures must be in place.

## 5.2 Submissions and Approvals

The Developer is responsible for being aware of the relevant regulatory requirements governing the development of the storm drainage system, and for compliance with these requirements. Since the City's storm drainage system discharges into Saskatchewan, the guidelines set forth by the Water Security Agency of Saskatchewan and the Province of Saskatchewan tend to govern storm water, however any wetlands or other bodies of water existing or constructed in Alberta must also comply with the requirements set forth by the Province of Alberta. Regulatory and supporting documents that must be referenced for the design and installation of the storm drainage system include, but are not limited to:

- These Municipal Development Standards and Standard Drawings;
- "Sewer Use Bylaw", City of Lloydminster;
- "Stormwater Guidelines" – EPB 322, Water Security Agency of Saskatchewan;
- "Wetland Design Guidelines Report", prepared for the City of Saskatoon by CH2MHILL;
- "The Environmental Management and Protection Act", Province of Saskatchewan;
- "The Water Regulations", Province of Saskatchewan;
- "Stormwater Management Guidelines for the Province of Alberta", Province of Alberta;
- "The Water Act", Province of Alberta;
- "The Environmental Protection and Enhancement Act", Province of Alberta;
- "The Occupational Health and Safety Act", Province of Saskatchewan or Alberta, dependent on which province the development is in;
- "National Building Code", Canadian Commission on Building and Fire Codes, National Research Council of Canada;
- "The Fisheries Act", Department of Fisheries and Oceans;
- "The Canadian Environmental Protection Act", Environment Canada;
- "Canadian Water Quality Guidelines", Environment Canada;
- PVC Pipe: Design and Installation" – M23, American Water Works Association (AWWA); and
- PE Pipe: Design and Installation" – M55, AWWA.

### 5.2.1 Stormwater Management Plan

Stormwater runoff generated from within the subdivision must be routed through a stormwater management facility as required to regulate the rate of outflow prior to discharge, unless otherwise approved by the City.

Stormwater management facilities must be designed in accordance with the current "Stormwater Guidelines" EPB 322 prepared by the Water Security Agency of Saskatchewan. Stormwater management facilities within

Alberta must also be designed in accordance with the current “Stormwater Management Guidelines for the Province of Alberta”. Approval of the design from Alberta Environment must be provided prior to construction.

A phased construction approach to match the expected development sequence may be acceptable upon approval by the City, provided the requirements of these guidelines are met.

Prior to submission of any detailed design, a stormwater management plan must be prepared by the Developer that is acceptable to the City, in accordance with the requirements outlined in Section 2.3.4.4. The stormwater management plan must be consistent with the Standards outlined herein, and must:

- Be in accordance with the City of Lloydminster Storm Drainage Master Plan;
- Identify the impact of the proposed development on the watershed;
- Identify and quantify the amount of upstream drainage entering onto the proposed development lands, including all points of entry;
- Identify all existing flow channels, drainage patterns or routes and containment areas;
- Identify the Major System hydraulic grade line;
- Identify the point(s) of discharge from the lands, as well as the type and calculated capacity of the receiving drainage facility(s), whether natural, man-made or a combination of both;
- Provide details of required stormwater retention/detention facilities;
- Provide details of water quality enhancement facilities; and
- Identify all licensing requirements as may be required by the Water Security Agency of Saskatchewan.

### 5.2.2 Erosion and Sedimentation Control Plan

As specified in Section 2.4.8, all developments must have an Erosion and Sedimentation Control (ESC) Plan submitted for review and approval by the City. The specific requirements of the ESC Plan are detailed in Section 5.8.

## 5.3 Design Flows

Design flows must be computed using either the Rational formula (for systems up to 50 hectares in area), or the hydrograph method.

### 5.3.1 Rational Formula

Design flows are to be calculated using the Rational Formula:

$$Q = \frac{CIA}{360}$$

Where: Q = Design flow in $m^3/s$
A = Drainage area in ha
I = Rainfall intensity in mm/hr (see Table 5.1)
C = Runoff coefficient

The rational formula is allowable for the minor system storm sewer main design for watersheds (less than 50 ha) which discharge into detention facilities or other outlets as approved by the City.

**Table 5.1 – Rainfall Intensity-Duration-Frequency Data for Lloydminster**

| Duration | | Rainfall Intensity (mm/hr) for Various Return Periods | | | | | |
|---|---|---|---|---|---|---|---|
| Minutes | Hours | 1:2 years | 1:5 years | 1:10 years | 1:25 years | 1:50 years | 1:100 years |
| 5 | | 81.0 | 126 | 152 | 190 | 207 | 231 |
| 10 | | 57.9 | 86.8 | 105 | 130 | 143 | 182 |
| 60 | 1 | 17.5 | 24.9 | 30.2 | 36.4 | 40.7 | 63.1 |
| 1440 | 24 | 1.41 | 1.98 | 2.34 | 2.81 | 3.16 | 4.57 |

Note: Use the IDF curve equation and parameters in Table 5.2 for intermediate values.

### 5.3.2 Parametric Representation of IDF Curves

Rainfall intensities not represented in Table 5.1 can be calculated using the following IDF curve equation:

$I = a(t + c)^b$ (for values of $t \geq 5$ minutes)

Where: I = Rainfall intensity in mm/hr
t = Time of concentration (minutes)
a, b, c = Parameters outlined in Table 5.2

**Table 5.2 – IDF Curve Equation Parameters**

| Parameters | Return Frequency | | | | | |
|---|---|---|---|---|---|---|
| | 1:2 years | 1:5 years | 1:10 years | 1:25 years | 1:50 years | 1:100 years |
| a | 512 | 718 | 913 | 1095 | 1230 | 2575 |
| b | -0.81 | -0.81 | -0.82 | -0.82 | -0.82 | -0.87 |
| c (min) | 4.74 | 3.57 | 3.91 | 3.48 | 3.8 | 11 |

### 5.3.3 Hydrograph Methods

Computer modelling must be used for stormwater drainage design for:

- Residential and commercial/industrial development areas greater than 50 hectares in size; and
- Any development requiring storage or detention facilities.

Acceptable computer models are the SWMM/XPSWMM models. Other models must be approved by the City prior to design.

### 5.3.4 Coefficient of Runoff

The coefficients of runoff for 1:5 year and 1:100 year return periods must be taken from Table 5.3:

**Table 5.3 – Recommended Runoff Coefficients for Storm Drainage Design**

| Land Use | Land Use District | Imperviousness | Rational Method C | |
|---|---|---|---|---|
| | | % | 1:5 Year | 1:100 Year |
| Parks/Playgrounds | UP | 10 | 0.25 | 0.35 |
| Schools/Institutional | PS | 40 | 0.45 | 0.55 |
| Residential - low density (detached/ semi-detached) | R1, R1L, R2 | 40 | 0.45 | 0.55 |
| Mobile Home Park | RMH | 50 | 0.55 | 0.65 |
| Residential - medium density (townhouse/rowhouse) | R3, R4 | 60 | 0.60 | 0.70 |
| Residential - high density (apartments) | R5 | 70 | 0.70 | 0.75 |
| Light Industrial | I1, I2 | 70 | 0.70 | 0.75 |
| Heavy Industrial | I3 | 60 | 0.60 | 0.70 |
| Neighbourhood Commercial | C3 | 80 | 0.75 | 0.80 |
| Commercial | C1, C2, C4, C5, DC1, DC2, DC3, DC4, DC5, DC6, DC7 | 90 | 0.85 | 0.90 |
| Country Residential | UT | 10 | 0.25 | 0.35 |

### 5.3.5 Rate of Precipitation

The most updated rainfall curves available for the area of development should be selected for design purposes.

The 5-year frequency curve must be used for all minor systems. The 100-year frequency curve must be used for major systems.

The maximum inlet time will be ten (10) minutes for residential and commercial land use area and fifteen (15) minutes for industrial land use areas. The combination of inlet time and pipe travel time will be combined to produce the time of concentration used to calculate the rainfall intensity.

## 5.4 Property Drainage

The establishment of an overall lot grading plan is a critical component of the major drainage system; it establishes the flow of water from the individual lots to the roadways, and is used in the calculation of the depth of flow in roadways during a major rain event. The lot grading plan is a specific requirement within the detailed engineering design drawings for a subdivision under the terms of a standard development agreement.

Site grading must ensure proper drainage of individual private properties or establish an effective surface drainage system for a whole development area. A lot grading plan will establish the drainage relationship between adjacent properties and its approval is an effective basis for the control of grading of the properties.

### 5.4.1 Site and Lot Grading

Standard Drawings 8-100, 8-101, and the following criteria must be used when creating a lot grading plan:

- Each lot must be graded to drain to the municipal storm drainage system, independently of adjacent lots, where possible;
- Lots lower than adjacent roadways are not permissible in urban areas;
- To provide basic positive drainage until a lot is developed, the lot(s) must be rough graded, allowing for earth balancing of future basement excavation and landscaping;
- Property corner and high point design elevations are to be established such that single family residential lots have a minimum overall slope of 2% from the high point to the front or back property lines for split drainage, or between the higher and lower, front and rear property lines with through drainage. This minimum grade should normally be exceeded where topography allows; and
- Split drainage is only permitted where the lot is located such that there is a road, lane, Municipal Reserve, Public Utility Lot, Municipal Utility Lot, or drainage easement located at both the front and back of the lot.

### 5.4.2 Use of Swales

The use of swales crossing numerous properties for collection of runoff and drainage control is not permitted unless justification is produced and documented to the satisfaction of the City, indicating that no other alternative is feasible.

If the City approves a swale to drain numerous properties, it must be covered by an easement in favour of the City of Lloydminster, to the satisfaction of the City. This swale would be designed to contain the 1:5 year storm flow within the concrete gutter, and the 1:100 year flow within the easement. Discharge from such a swale that would cross a walkway must instead be intercepted by a catch basin with sufficient capacity to contain the 1:5 year event. Ponding depth must be limited to 300 mm, with a maximum 1:5 slope around the catch basin cover. Calculations for the swale’s minor and major flow capacities must be included with the engineering design drawings.

Detailed requirements for swales:

- Drainage through one or more lots must be defined by a minimum 500 mm wide (nominal size) concrete swale. See Standard Drawing 8-200;
- Concrete swales will require a minimum of a 2.0 m easement;
- Concrete swales must have a minimum slope of 0.6% and a maximum grade of 4:1;
- Grassed swales must have a minimum slope of 1.5% and a maximum grade of 4:1; and
- Swales should be aligned as straight as possible and sudden or sharp deflections of greater than 45° are not permissible.

## 5.5 Minor System Design

Minor drainage systems consist of pipes, open channels and water courses that convey peak flows of a 5-year return period rainfall event. This system must accommodate the contribution of serviced lots, which must have a private underground storm sewer service provided. Ponding or surcharging of water may be of a depth up to 300 mm.

### 5.5.1 Storm Sewer Services

Storm services must discharge to a storm sewer system. The following criteria must be used in the design of storm services:

- A storm sewer service must not be discharged or connected to the sanitary system under any circumstances;
- Storm sewer service connections must be designed as a single connection from the main to the property line, straight in to the building at a right angle to the main. The exception to this is service connections at the end of cul-de-sac bulbs, which may be connected directly to the manhole where a right angle connection to the main is not possible;
- It is preferred that storm sewer service connections to PVC mains 300 mm or smaller be made by the use of in-line tees, otherwise saddles are to be used. Concrete and open profile or ribbed PVC mains require the use of inserted tees. See Standard Drawings 7-101, 7-102 and 7-103;
- Preferably the depth of the storm service should match that of the sanitary sewer service at the property line, 2.85 m from invert to proposed finished grade. Otherwise the storm service must be a minimum depth of 1.5 m from top of service pipe to finished grade at the property line. If the storm service minimum depth cannot be achieved, a storm servicing plan must be submitted to the City for approval;
- Storm sewer service stubs must be extended 4.0 m past the property line, or 2.0m past the shallow utility easement, whichever is further; and
- Size the storm services with a minimum size of 100 mm for residential properties and 150 mm for commercial or industrial properties, 300 mm if connected to catch basins;
- Pipe materials are restricted to PSM type PVC SDR 35.

## 5.5.2 Flow Capacities

### 5.5.2.1 Storm Sewers and Open Channels

The design flows and capacities of storm sewers and open channels must be calculated using Manning's formula:

$$Q=\frac{AR^{0.667}S^{0.5}}{n}$$

Where: Q = Design flow in $m^3/s$
A = Cross sectional area in $m^2$
R = Hydraulic radius (area/wetted perimeter) in m
S = Slope of hydraulic grade line in m/m
n = Roughness coefficient:
= 0.013 for all smooth-walled pipe
= 0.024 for corrugated steel pipe (unpaved)
= 0.020 for corrugated steel pipe (invert paved)
= 0.020 for gravel lined channels
= 0.015 for concrete or asphalt lined channels
= 0.05 for natural streams and grassed channels

It is preferred that designs utilize no more than 85 percent of a pipe's maximum capacity, and that gravity flow be used where possible.

## 5.5.3 Pipe Location

Where at all possible, water mains should cross above sewer mains. The minimum separation of the storm sewer main from water mains, sanitary sewer mains, and power/telephone/cable is as follows:

- Minimum 3.0 m horizontally unless sewer depth requires increased spacing;
- Minimum 0.6 m vertical clearance between the bottom of a sewer pipe and the top of the watermain, if the watermain is passing under; and
- Minimum 0.3 m vertical separation between the top of a sewer pipe and the bottom of the watermain, if the watermain is passing over.

Pipes being crossed must be supported as shown in Standard Drawing 4-300.

### 5.5.4 Minimum Depth of Cover

The minimum depth of cover is as follows:

- Storm sewer pipes — minimum 1.5 m to obvert
- Catch basin leads at the catch basin — minimum 1.4 m to obvert

### 5.5.5 Minimum Pipe Diameter

Sizing of pipes will adhere to the recommendations within the Stormwater Master Plan; otherwise the following minimum sizes will be used:

- Storm sewer mains connected to storm services only — 200 mm
- Storm sewer mains connected to catch basins — 300 mm
- Culverts — 400 mm
- Catch basin leads — 250 mm
- Catch basin leads for downstream catch basins connected in series — 300 mm
- Residential storm services — 100 mm
- Commercial/industrial storm services only connected to buildings — 150 mm
- Commercial/industrial storm services connected to catch basins — 300 mm

### 5.5.6 Minimum Velocity and Grade

All storm sewers must be designed with mean minimum velocities of 0.90 m/s, based on Manning's formula, when flowing full. Mean velocities below 0.90 m/s will not be allowed.

Storm sewers with mean velocities in excess of 3.0 m/s must be designed appropriately to protect against displacement of sewers by erosion or shock.

While steeper grades are desirable, the minimum grades are in Table 5.4.

**Table 5.4 – Minimum Pipe Grades**

| Internal Pipe Diameter (mm) | Minimum Grade (%) |
|---|---|
| 200 | 0.74 (no catch basins connected) |
| 250 | 0.55 (no catch basins connected) |
| 300 | 0.44 |
| 375 | 0.32 |
| 450 | 0.26 |
| 525 | 0.22 |
| 600 | 0.18 |
| 675 | 0.15 |
| 750 | 0.13 |
| 900 and larger | 0.10 |

### 5.5.7 Curved Sewers

For storm sewers aligned in a curve:

- Maximum joint deflection must have a radius greater than 60 m, unless otherwise recommended by the pipe manufacturer; and

- Curved sewers must be aligned parallel to the road centreline.

While steeper grades are desirable, the minimum grades are in Table 5.5.

**Table 5.5 – Minimum Curved Pipe Grades**

| Internal Pipe Diameter (mm) | Minimum Grade (%) |
|---|---|
| 200 | 0.85 (no catch basins connected) |
| 250 | 0.63 (no catch basins connected) |
| 300 | 0.50 |
| 375 | 0.37 |
| 450 | 0.29 |
| 525 | 0.24 |
| 600 | 0.20 |
| 675 | 0.17 |
| 750 | 0.15 |
| 900 | 0.12 |
| 1050 and larger | 0.10 |

### 5.5.8 Hydraulic Losses Across Manholes

The design of manholes must conform to the following:

- Generally, for increasing pipe diameters, the obvert of the downstream pipe will match the obvert of the upstream pipe. The obvert of the downstream pipe must not be higher than that of the upstream pipe;
- Minimum drop in invert levels across manholes to account for energy loss:
  - Straight runs – 20 mm drop minimum;
  - Deflections up to 45º - 30 mm drop minimum;
  - Deflections 45º to 90º - 60 mm drop minimum;
- Deflections greater than 90° must be accommodated using two (2) or more manholes;
- A smooth transition will be provided between the inverts of incoming sewers and the outlet sewers. Extreme changes in elevation at manholes will be avoided;
- Where drops greater than 1.0 m cannot be avoided, a specifically designed drop manhole will be required to address the hydraulic requirements of the change of elevation. Considerations include:
  - The pipe must be of sufficient size so that it does not surcharge;
  - A smooth vertical curve must be formed between the inlet pipe and the drop shaft with no breaks in grade, projections, or edges;
  - The drop shaft diameter must be equal to or greater in size than that of the largest inlet pipe. For multiple connections, a larger drop shaft must be supplied;
  - An air vent is to be provided at the crown of the outlet pipe downstream as detailed in Standard Drawing 3-103.
  - The outlet must provide a hydraulic jump basin to dissipate energy, to convert the flow to sub-critical velocity, and to allow for air release;
  - The cover must be able to withstand pressures from air discharge and surcharging; and
  - The manhole shaft must be sized to attain a clear main entry access of 1.0 m or greater.

### 5.5.9 Manhole Spacing

Manholes must be provided at the end of each line, at all junctions, and at all changes in pipe sizes, grade and alignment.

The distance between manholes must not be greater than 120 m for sewers 900 mm and smaller, and 150 m for sewers larger than 900 mm.

For curved sewers, manhole spacing is a maximum of 90 m for sewers 1200 mm and smaller, and 120 m for sewers larger than 1200 mm.

### 5.5.10 Catch Basins

The selection and design of catch basins must conform to the following:

- Catch basins must be of sufficient number and have sufficient inlet capacities and adequate catch basin leads to receive and convey the calculated stormwater flow;
- Catch basins must be provided to intercept surface runoff and must be spaced a maximum of every 120 m. The distance to the first catch basin from the high point must not be greater than 120 m;
- Catch basins must be a minimum of 900 mm diameter, see Standard Drawings 5-100 and 5-101 and Table 5.6;
- All catch basin bodies must be poured in place or precast concrete sections conforming to the most recent ASTM specifications and constructed to provide a minimum 500 mm sump to trap rocks and gravel;
- Catch basin leads must be installed to provide a minimum depth of cover, from the design finish grade, of 1.4 m to obvert unless otherwise approved. The minimum slope on catch basin leads must be 2% and a maximum length of 30 m;
- It is preferred that all catch basin leads discharge directly into stormwater manholes. A catch basin may discharge into a second catch basin, provided that the lead from the downstream catch basin has sufficient capacity to carry the accumulated flow from both catch basins. This lead must have a minimum size of 300 mm;
- All catch basin leads must be open profile PVC pipe;
- Catch basin leads greater than 20.0 m in length will use 300 mm diameter pipes;
- Catch basins using F-51 or DK-7 covers will use minimum 300 mm diameter leads;
- Catch basin installation should be upstream of any crosswalk whenever possible;
- Catch basins installed in MR spaces will utilize locking grates;
- Catch basins installed as ditch or drainage channel inlets will utilize trash grates (Norwood Foundry or approved equivalent); and
- Catch basins must utilize an approved frame and cover for the application, as detailed in Table 5.6.

**Table 5.6 – Catch Basin Materials**

| Frame & Cover Type | Curb Type | Min. Barrel Size (mm) | Allowable Application |
|---|---|---|---|
| F-36 | Straight Face | 900 | Catch basins only |
| F-36A | Straight Face | 1200 | Catch basin manholes only |
| F-39 Round Top | No Curb | 900 | For temporary inlets on roadways |
| F-39 Locking Cover | No Curb | 900 | For grassed areas or areas not in the roadway |
| F-39 Trash Grate | No Curb | 900 | For ditch/channel inlets |
| K7 | 80 mm rolled face | 900 | Current preferred inlet for residential areas |
| DK7 | 80 mm rolled face | 900 | Preferred for residential areas where additional capacity is needed |
| F-38 | No Curb | 900 | Lanes, swales, gutters and curb ramps |
| F-51 (no side inlet) | No Curb | 900 | For use on arterial roadways |
| F-51 (with side inlet) | Straight Face | 900 | For use on arterial roadways |
| F-50 shallow frame TF-GL locking grate | No Curb | 900 | For use in parks or grassed areas |

## 5.5.11 Pipe, Manhole and Bedding Materials and Specifications

### 5.5.11.1 Pipe Materials

Pipe material selected must comply with the specifications in Table 5.7.

**Table 5.7 – Acceptable Pipe Materials**

| Material | Range (mm) | Specification |
|---|---|---|
| Reinforced Concrete | 300 and up | CAN/CSA A257 Class 3 min. |
| PVC – Solid Wall | 200 to 900 | CAN/CSA B182.2 Min. Class DR35 |
| PVC Profile (Ultra-Rib, KorFlo) | 300 to 900 | CSA-B182.4, 320 kPa pipe stiffness |
| Steel Reinforced PE (DuroMaxx) | 750 to 3000 | ASTM D3350, ASTM F2562, CSA B182.14, AASHTO-MP-20 |
| Corrugated Steel Culverts | 400 and up | AASHTO-M-36 (Storm only) |

Pipe must be jointed with rubber gaskets or gasketed fittings or couplings.

### 5.5.11.2 Manholes

All manholes are to be 1200 mm inside diameter or larger for pipes up to 600 mm, and 1500 mm inside diameter or larger for pipes 600 mm to 900 mm inside diameter, as per section 3 of the Standard Drawings. Manholes for pipes 1050 mm inside diameter or larger will utilize a t-riser manhole, as per Standard Drawing 3-102. Manhole selection and design must conform to the following:

- Manholes must be large enough to accommodate the maximum intersecting pipe size. The minimum distance between pipe openings must be 225 mm or one half of the largest pipe's outer diameter, whichever is greater. See Standard Drawing 3-207;
- Manholes must be designed with sufficient inside dimensions to perform inspection and cleaning operations, allow for proper channel construction without difficulty, and minimize hydraulic losses through the manhole;
- Buoyancy calculations must be provided to the City for all manholes that have half or more of their vertical depth below the surrounding water table elevation;
- Manholes must be manufactured using sulphate resistant Type HS cement;
- Manhole sections must be precast reinforced concrete sections conforming to ASTM C478 and CSA A257.4;
- Manhole steps must be standard safety type, aluminum forged of 6061-76 alloy having a minimum tensile strength of 200 MPa;
- All joints must be sealed with rubber gaskets conforming to ASTM C443 and grouted inside and outside with non-shrink grout;
- Manholes must be fitted with the appropriate cast iron frame and cover conforming to Class 20 ASTM A48 as shown in section 3 (Manholes) of the Standard Drawings. Manholes installed in roadways must utilize an F-80 floating frame as detailed in Standard Drawing 3-202 and a TF-80LSTM Storm Sewer Cover as detailed in Standard Drawing 3-205. Manholes installed in grassed areas must utilize F-39 frames with locking covers, as detailed in Standard Drawing 3-208. All castings must be true to form and dimensions, free from faults, sponginess, cracks, blowholes, or other defects affecting their strength;
- Pre-benched manhole bases must be used wherever possible with pre-cored connection holes and water tight Duraseal or G-Loc joints or approved equivalent;
- Tee Riser manholes must conform to CSA 257.2/ASTM C76 (pipe components) and CSA A257.4/ASTM C76 (manhole riser component); and
- Aluminum safety platforms are required in all manholes with a depth greater than 5.0 m. See Standard Drawing 3-201.

### 5.5.11.3 Bedding Material

Bedding material must be designed in accordance with the parameters specified in Section 4.14.4.

### 5.5.11.4 Outfall Structures

The design of outfall structures must conform to the following:

- For all outfalls, it is required that a hydraulic analysis be completed to ensure that the exit velocities will not damage natural watercourses. Final velocities into a natural drainage course must not exceed 1.5 m/s;
- Appropriate erosion control measures, including energy dissipaters, are to be provided downstream of the outfall to prevent erosion;
- All sewer outlets must be constructed with lockable grates to allow maintenance but prevent entrance of unauthorized personnel. Where required, guardrails and/or fences must be installed to provide fall protection; and

- Outfall structures must be designed with consideration of aesthetics, as they are generally located within parks and on channels. Concrete surface treatment is recommended.

## 5.6 Major System Design

The Major System consists of surface flood paths, roadways, parkways and water courses which are designed to convey flows of a 100-year return period rainfall event. The system includes culverts crossing roadways and pipe systems downstream of stormwater management facilities.

Major System Conveyance elements must be designed to accommodate runoff rates and volumes for a 100-year return period rainfall event such that:

- The depth of peak flows and ponding in developed area streets, conveyance channels and swales are to be limited so that major system flows will not constitute a significant hazard to the public or result in significant erosion or other property damage;
- The maximum water surface level of surface flows and ponding in streets is below the lowest anticipated landscape grade or opening at any adjacent buildings, with a freeboard provision generally in the order of 300 mm with a minimum of 150 mm;
- Depths of flow and ponding are less than 300 mm in roadways, Municipal Reserves, Public Utility Lots and Municipal Utility Lots; and
- For arterial roadways, the water depth at the crown of the road must not exceed 150 mm.

### 5.6.1 Culverts

Use the inlet control and outlet control methods referred to in The Handbook of Steel Drainage and Highway Construction Products, by the Corrugated Steel Pipe Institute. The culvert must be designed to discharge:

- A 10 year event without static head at the entrance; and
- A 100 year event utilizing available head at the entrance.

The elevation of water from the 100 year event must allow for a freeboard of 0.5 m to the edge of the asphalt of the adjacent roadway.

Culvert design must comply with the requirements set forth in Section 5.7.

### 5.6.2 Stormwater Management and Storage Facilities

Stormwater management and storage facilities (SWMF) must be designed to meet the Water Security Agency of Saskatchewan Guidelines, and the requirements of this Section and Appendix 5C. Storage or detention facilities must be sized based on most critical rainfall event, based on the four hour modified Chicago or 24 hour Huff distribution, as well as to reach water quality targets. Tables with the design storm values can be found in Appendix 5B, and further details of the design parameters for storage facilities can be found in Appendix 5C.

#### 5.6.2.1 Design – Wet Ponds

Standard Drawing 5-500 illustrates the components of a wet pond. The design of wet ponds must, at a minimum, conform to the following:

- The pond must have a minimum surface area at normal water level of two (2) hectares;
- The pond must be sized such that there will be storage for a 1:100 year storm event to be contained within a maximum water depth fluctuation (buffer) of 2.0 m above the normal water level, and to achieve water quality targets. A minimum freeboard of 0.30 m above this high water level (HWL) must be provided. Adjacent property lines along the pond perimeter must be above the freeboard elevation;

- The pond must feature a forebay for each inlet with a minimum depth of 1.5 m to trap sediment before it enters the active storage of the pond. The area of the forebay must be less than one third of the area of the active storage area, separated from the active storage by an earthen berm submerged 0.15 to 0.30 m below the normal water level (NWL). The minimum length:width ratio of the forebay is 3:1, with 4:1 to 5:1 recommended;
- The active storage of the pond must be sized to achieve a minimum active storage detention time of 24 hours, and an 85% removal of total suspended solids (TSS) for particle sizes ≥ 50 µm. The minimum length:width ratio of the active storage is 3:1, with 4:1 to 5:1 recommended;
- The minimum active storage pond depth (NWL to bottom) must be the greater of 2.0 m, or a depth of 25 mm × the catchment area × the overall catchment imperviousness ratio. A 3.0 m depth should be provided where practical;
- There must be a minimum pond water turnover rate of twice per year based on the 1:5 year low precipitation rate as selected for the water balance within the city over the five (5) month period of May through September;
- An emergency overland drainage swale must be provided from the downstream end of the pond to the receiving stream with capacity to transport storm runoff should a downstream malfunction occur. This swale must be designed to convey water at a minimum rate of 1.0 $m^3/s$, and have sufficient erosion controls in place to withstand this flow rate;
- An impervious pond bottom and sides must be constructed having a permeability of $1 \times 10^{-6}$ cm/s or lower;
- Dead bay areas are not be permitted, and inlets and outlet should be located to maximize detention time and circulation, and to reduce short-circuiting though the pond;
- The obvert of all inlet and outlet structures must be submerged a minimum of 1.2 m below the normal water level and posted at the surface, see Standard Drawing 5-400. These structures must be accessible by vehicle for the purpose of maintenance. The invert of these structures must be 100 mm above the bottom elevation;
- The outlet control structure must feature an orifice, a minimum of 100 mm in diameter, sized to allow a design maximum release rate of 1.5 litres per second per hectare (L/s/ha) under the 1:5 year design storm, unless surface modelling indicates a lower release rate in the pre-development condition;
- The side slopes of the pond must not be steeper than 5:1 down to the NWL, with 7:1 preferred. From the NWL to 2 m horizontally, the slope must be 3:1. The remainder of the slope below NWL must be between 5:1 and 7:1;
- The normal water elevation must be such that the collection system must not surcharge to an elevation greater than the lowest catch basin invert in the collection system, under a 1:5 year storm;
- Naturalization of the shoreline is considered desirable, to improve the aesthetics of the pond, and discourage direct contact with the water; and
- Maintenance access from an adjacent street or lane must be provided to the outlet control structure, the inlet structure(s) or manholes and the forebays of the pond. Operations staff using 1 tonne trucks must be able to access all areas of the pond.

### 5.6.2.2 Design – Dry Ponds

The minimum design criteria specifically related to dry ponds are:

- All dry ponds must be off-line storage. A low flow bypass must direct storm runoff around the dry pond during minor rain events;
- The maximum depth of storage in a dry pond must be 1.5 m during a 1:100 year storm event;
- The minimum floor elevation for lots surrounding a dry pond must be 0.6 m above the HWL. The lowest building opening for lots surrounding a dry pond must be 1.6 m above the HWL;
- Grassed areas must have a minimum longitudinal slope of 1.0%. Grassed areas must have a minimum lateral slope of 1.5%. A 150 mm diameter weeping tile system must be installed 150

mm below the invert of the longitudinal slope to the pond outlet. This will reduce surface ponding along the longitudinal slope after the pond drains;

- Hard surface swales (concrete or asphalt) may be constructed along the longitudinal slope depending on the other planned uses for the park. The minimum slope for a hard surface swale is 0.6%;
- The side slopes on the dry pond must be no steeper than 5:1; and
- All inlet and outlet structures must be grated with a maximum bar spacing of 150 mm for safety purposes. Outlets should feature horizontal bars, and inlets should feature vertical bars, as per Standard Drawings 5-302 and 5-303, respectively.

#### 5.6.2.3 Constructed Wetlands

Wetland size should be approximately 5% of the watershed area that it will be servicing, and must comply with the "Wetland Design Guidelines" prepared for the City of Saskatoon by CH2MHILL, as well as meet the following design criteria:

- Approximately 10% of the wetland surface area should be a 1.5 to 2.0 m deep sediment forebay upstream of the wetland area for settled solids removal;
- Average permanent wetland water depth is 0.3 m with 1.0 m deep zones for flow redistribution and for fish and submerged or floating aquatic vegetation habitat;
- Active storage is 0.3 to 0.6 m deep;
- Length to width ratios can be as low as 1:1. Increase where required to maximize treatment and to prevent short-circuiting;
- Bottom slope of 0.5% to 1.0% is recommended, as well as a smooth bottom to promote sheet flow through the system;
- The wetland must be sized such that there will be storage for a 1:100 year storm event;
- Regulated inflow and outflow structures are required that will consider a wide range of rainfall intensities;
- Take advantage of natural topography, drainage patterns, etc.;
- Design in conjunction with a buffer and the surrounding land and aquatic systems;
- Design to protect the wetland from any potential high flows and sediment loads; and
- Design for self-sustainability and to minimize maintenance.

The design of the wetland must comply with the buffering and freeboard requirements for wet ponds described in Section 5.6.2.1.

#### 5.6.2.4 Erosion

Construction of new developments must be exercised in a manner such that erosion of the site and sediment discharge via runoff to the receiving stream is minimized. The design must be in compliance with the water quality requirements set forth in Section 5.8, as well as the following:

- Adequate erosion protection will be required for all natural and man-made water courses within the new development; and
- Outfalls of storm sewers must be designed to control local erosion to the conveyance channel or receiving stream and must not change the hydraulic characteristics of the receiving stream.

#### 5.6.2.5 Maintenance

The Developer will be responsible for any defects of the works and lands associated with the facility, including adjacent park lands, for the warranty period, including, but not limited to, the following:

- The Developer must assume full responsibility with respect to the operation and maintenance of the facilities in all aspects relating to flows, water volumes, surface debris, aeration, hydrological cycle, hydraulic performance, utility devices such as outlet structures, vegetation control, insect control and on-shore facilities until issuance of a Final Acceptance Certificate;

- The Developer will be responsible for silting and debris problems which are caused due to poor erosion control in the development. Should silting and debris problems occur in the ponds that are the result of stormwater draining from lands beyond the Developer's control, the City will assume responsibility for any necessary remedial actions; and
- The monitoring and maintenance of water quality to eliminate any nuisance factors and to protect against health hazards will be the responsibility of the Developer during the warranty period.

#### 5.6.2.6 SWMF Boundary Control and Use

The SWMF boundary will be determined utilizing the following criteria:

- The lot containing the stormwater storage facility must be sufficiently sized to wholly contain the 1:100 year design event;
- Land above the 1:100 year design flood level, must be protected by a restrictive covenant, registered against the title of the property, indicating that the land is subject to flooding and that the Owner will not construct any permanent structures susceptible to flood damage;
- Minimum lot dimensions and rear yard depths as measured from the property line must conform to the requirements of the City of Lloydminster Land Use Bylaw and the relevant Area Structure Plan.

#### 5.6.2.7 Site Acquisition and Financing of Construction

The acquisition of all SWMF sites must occur prior to subdivision approval and at no cost to the City. In addition, all lands acquired for the SWMF site must be excluded from all subsequent area structure plans or outline and tentative plans for the purposes of roadway, public/municipal utility, density, and potential municipal reserve calculations in any plans prepared for the area. The parcel of land acquired must be designated as a Public Utility Lot in Alberta or Municipal Utility Parcel in Saskatchewan. All design and construction of stormwater ponds, interconnecting pipe systems and outfall lines must be completed with the City's approval and paid for by the Developer. Where the development utilizes an existing system or the work is undertaken by others, the City will recover the costs from the Developer through off-site levies or contribution agreements.

#### 5.6.2.8 Legal Liability and Safety

Given that direct water contact by the public will be discouraged, supervision will not be provided. Proper and adequate signage to alert people to the potential hazards (No Swimming – Deep Water, subject to flooding, etc.) must be provided by the Developer in a number and locations specified by the City, see Standard Drawings 5-401, 5-402 and 5-403. Fencing of municipal park areas will be determined during the detailed design stage and provided by the Developer.

### 5.6.3 Drainage Parkways

Drainage parkways, if approved by the City, may be utilized to convey large volumes of storm water under controlled conditions through or past the subdivision. Drainage parkways must be designed in accordance with the "Stormwater Guidelines" published by the Water Security Agency of Saskatchewan and good engineering practice.

The minimum drainage parkway cross section will be as follows:

- 3.0 m bottom sloped to drain to a low flow trickle channel to be installed in the bottom;
- Maximum side slopes of 5:1;
- Terraced side slopes when depth exceeds 3.0 m or for amenities such as trails or treed terraces;

- 3.0 m wide sloped terrace;
- 1.5 m clearance between top of excavation and property lines; and
- The area above the 1:25 year flood elevation must be landscaped for recreational uses, complete with trails, benches, trees, etc.

## 5.7 Ditch and Culvert Design

Culverts for the use of storm drainage will require approval from the City. Piped storm drainage will be a requirement whenever feasible.

The ditch grade must be no less than 0.5%. Ditch grades in excess of 2.0% must be protected against erosion through methods such as rock ditch checks, silt fences, Enviroberm fences and/or erosion control blankets.

The ditch bottom width must be no less than 1.5 m, sloping away from the roadway at a minimum of 5.0%.

Culvert size requirements must be determined through the stormwater drainage analysis, however culverts crossing a roadway must be at least 600 mm in diameter.

Culverts must be made of approved materials. Corrugated metal pipe must have a minimum wall thickness of 1.6 mm for pipe sizes of 600 mm and 2.0 mm for pipe sizes up to 900 mm, or as required by the loading criteria. The corrugation pattern must be 68 mm pitch and 13 mm depth. All culverts must be installed in accordance with the manufacturer's recommendations, bedded on granular base, and must be installed complete with bevelled end sections on both the inlet and outlet ends with the invert extended to the toe of the side slope.

Culverts must be installed to provide a minimum depth of cover of 500 mm or one-half (½) the culvert diameter, whichever is greater, as measured from the finished shoulder grade of the roadway to the top of the culvert. This cover material must be compacted to a minimum of 100% Standard Proctor Density before any equipment or vehicles are permitted to travel over it.

Riprap must be placed around the inlet and outlet of all culverts. Riprap material will consist of rock ranging in size from 150 mm to 350 mm with 50% of the rock material being larger than 200 mm. Typical riprap installations are illustrated in Standard Drawings 5-300 and 5-304.

## 5.8 Water Quality Considerations

The transport of sediment and other deleterious material into the City's stormwater system results in increased maintenance costs in the form of flushing, as well as increased wear on the infrastructure due to abrasion thus shortening its lifespan. This also causes a reduction in water quality, not only due to the sediment, but also any contaminants it has absorbed. The Sewer Use Bylaw was implemented by the City in order to control the discharge of pollutants into the wastewater system and thus protect the environment.

### 5.8.1 Erosion and Sedimentation Control

All storm drainage systems, including pipe outlets and other drainage channel outlets or overflows, must be designed to control erosion that may result from piped or overland stormwater flows and discharge into the storm drainage system. In order to facilitate the control of erosion and the prevention of the transportation of sediment, all Developers will be required, as a part of their Development Agreement or Development Permit, to supply an Erosion and Sedimentation Control (ESC) plan for approval by the City. The City may, at its sole discretion, waive portions of the ESC requirements detailed herein, based upon the scale of the Development.

Developers will conform to the relevant portions of the most recent edition of the City of Edmonton's Erosion and Sedimentation Control Guidelines ("the Guidelines"), specifically the following sections:

- 4.2.5 – Neighbourhood Design Report

- 4.2.6 – Engineering Drawings
- 4.4 – Pre-Construction – Stripping and Grading
- 4.5 – Construction and Post-Construction

Section 5 of the Guidelines details the preparation of an ESC plan, Section 6 covers monitoring, maintenance and record keeping procedures, and Section 7 provides examples of commonly used Best Management Practices (BMPs), both temporary measures for use during construction and permanent measures that will be left in place after the maintenance period.

The Erosion and Sedimentation Control Field manual is an excellent resource, and is intended to assist field representatives of consultants, contractors and inspectors in their respective roles in development of a site.

#### 5.8.1.1 ESC Strategy

As discussed in Section 4.2.5 of the ESC Guidelines, at the Area Structure Plan stage of a subdivision, an ESC Strategy must be prepared (or as part of the Outline Plan, where there is no Area Structure Plan). This strategy will demonstrate how erosion and sediment control will be implemented over the entire area, broken down into subdivision phases, identifying:

- Potential off-site or downstream impacts;
- An evaluation of areas susceptible to erosion;
- All critical areas that require erosion protection and proposed measures for erosion control;
- Details of proposed sedimentation control facilities;
- Anticipated sediment loadings and sediment removal schedule;
- Location, purpose and capacity of permanent BMPs, and a conceptual plan for temporary BMPs;
- Approximate limits of clearing and grading, buffer strips, vegetation to be retained, etc.;
- Timing/sequencing of stripping and grading activities; and
- Any unique challenges or approaches anticipated.

#### 5.8.1.2 ESC Plan

At the detailed design stage, an ESC Plan must be prepared by the Engineering Consultant, following the framework set out in the ESC Strategy. The ESC Plan will identify the temporary and permanent measures to be implemented throughout the construction and post-construction periods, and who is responsible to implement, monitor and maintain them, to mitigate any potential sedimentation and erosion problems both within the development, and in downstream developments or areas.

Note that the City's review and approval of the ESC Plan serves as a record of receipt, not a determination of the effectiveness of the Plan. The ultimate responsibility for the Plan, its implementation, and its effectiveness rests solely on the Developer.

Following Development Agreement approval, any revisions to the permanent BMPs must be reviewed and approved by the City, following the procedure outlined in Section 2.2.3 of these Standards. Modifications to the temporary BMPs do not require approval of the City, as the Developer may need to adjust the Plan during construction as needed, however the City should be informed of the change(s) in a timely manner. Flexibility to modify the ESC Plan should not be taken as entitlement to eliminate or fail to implement a satisfactory ESC Plan; the Developer is ultimately responsible for any site discharge which is not compliant with regulatory requirements.

Section 5 of the Guidelines discusses the preparation and required content of an ESC Plan in great detail. The requirements for the report, drawings, and calculations are summarized below. Appendix A of the Guidelines provides a checklist of the minimum requirements of an ESC Plan. The ESC Plan must be a stand-alone document that can be located on the construction site for use by site personnel, inspectors and regulators. As site work progresses, the ESC Plan should be modified by the Engineering Consultant and/or Contractor, in consultation with City staff, to reflect changing conditions.

#### 5.8.1.2.1. ESC Report

The ESC report is a brief description of the overall strategy for ESC. It should summarize the aspects of the project that are important for erosion and sedimentation control and should include:

- A brief description of the proposed land-disturbing activities, existing site conditions and adjacent areas (such as creeks and buildings) that might be affected by the land disturbance;
- A description of critical areas on the site including areas that have potential for serious erosion problems such as severe grades, highly erodible soils, and areas near wetlands or water bodies;
- A construction schedule that includes the date stripping and grading operations will begin and the expected date of stabilization;
- A brief description of the BMPs that will be used to minimize erosion and control sedimentation on the site, when they will be installed, and where they will be located;
- An inspection and maintenance program, including frequency of inspection, reseeding, repair and reconstruction of damaged structures, cleanout and disposal of trapped sediment, duration of maintenance program, and final disposition of the BMPs when site work is complete;
- Shutdown plans where construction activities are delayed for an extended period of time. ESC shutdown plans need to address ongoing maintenance and inspection issues;
- An emergency response plan that identifies available short-term resources in terms of personnel, equipment, and BMPs, and steps to be taken for incident reporting to regulatory authorities where discharge of sediment exceeds regulatory requirements; and
- Name and signature of person preparing the plan and professional stamp/designation.

Special issues that may need to be addressed include:

- Sensitive Area Protection:
  - Show on-site and off-site drainage basins that flow through the area;
  - Delineate all lakes, ponds, wetlands, impoundments, intermittent or continuous streams and show proposed protection measures; and
  - Indicate any slopes greater than 20% on preliminary and final contours and show proposed protection measures for each stage of grading;
- Inlet Protection:
  - Show the storm drain system complete with size and location of storm drains, inlets, pipes, basins, etc.;
  - Provide diversions, where applicable, to divert clear water around disturbed areas;
  - Indicate where the stormwater discharges and what measures exist or will be installed to prevent erosion and dissipate the flow energy; and

- Show the location and type of all inlet sedimentation control BMPs.

#### 5.8.1.2.2. Drawings

Drawings supporting the Erosion and Sedimentation Control Plan will include the following:

- Existing and final site contours at an interval and scale sufficient for distinguishing runoff patterns before and after soil disturbance;
- Existing vegetation, such as grassy areas or vegetative buffers, that may reduce erosion or off-site sedimentation;
- Limits of clearing and grading;
- Critical areas within or near the project areas, such as streams, lakes, ponds, wetlands, highly erodible soils, public streets, and residences;
- Locations and types of ESC measures, with dimensions; and
- Detailed drawings of ESC structures and measures, showing dimensions, materials, and other important details.

#### 5.8.1.2.3. Calculations

Calculations/specifications that may be required include:

- Design criteria and calculations such as design particle size for sediment basins and peak discharge for channel design and outlets;
- Calculations to demonstrate the design sediment removal efficiency from the runoff from the site as a percentage;
- Seeding or vegetative specifications;
- Inspection and maintenance notes;
- Sedimentation Control:
  - Provide sediment traps for areas less than two (2) hectares complete with design calculations;
  - Provide sediment basins for areas of two (2) hectares or greater complete with design calculations;
  - Show any other storm water management facilities complete with operating conditions; and
  - Provide pipe end treatments and flow control devices to prevent channel erosion.
- Utility Lines and Water Crossings:
  - Provide sediment traps for dewatering activities; and
  - Provide details for all water crossings.

### 5.8.1.3 Construction and Post-Construction

During the construction phase, the Developer is responsible for ensuring that all individuals working on the site are familiar with and are following the ESC Plan, and are undertaking the required monitoring and maintenance of all temporary and permanent BMPs at the site. Chapter 6 of the ESC Guidelines details the requirements and responsibilities for maintenance and monitoring of temporary and permanent BMPs from the start of construction through to post-construction. The responsibility for monitoring and maintaining the BMPs is primarily that of the Developer. Permanent BMPs must be maintained by the Developer until the FAC is issued. Temporary BMPs must be maintained by the Developer until they are no longer needed, at which time they must be removed. BMPs should be inspected at least one (1) time per week, and after heavy rainstorms or snowmelt events. Inspection reports must be kept, as described in Section 6 of the Guidelines. While the Developer is not required to submit copies of these reports to the City, a request may be made from time to time to review copies of the reports and ESC documentation, to determine their existence and extent.

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# TABLE OF CONTENTS

# Appendix 5A - STORM SEWER SPECIFICATIONS

## 5A.1 Pipe Installation

Installation of pipes will conform to the following subsections.

### 5A.1.1 Bedding

For Class A bedding, the sewer pipe will be bedded and cradled in 32 MPa concrete to the depths shown on Standard Drawing 4-200.

For Class B bedding, the sewer pipe will be bedded in compacted granular material, which will have a thickness as shown on Standard Drawing 4-200. The granular material will be compacted to 95% Standard Proctor Density for the full width of the trench up to 300 mm above the crown of the pipe.

### 5A.1.2 Pipe

Concrete pipe lifting holes are to be sealed with pre-fabricated plugs after installation of the pipe.

PVC pipe age is not to exceed two years at the time of installation.

Pipes and fittings are to be clean of debris and water before installation. Pipes are to be laid and joined as per the manufacturer's recommendations. Whenever work is suspended, install a removable water-tight bulkhead at the open end of the last pipe laid to prevent the entry of foreign materials.

Make watertight connections to manholes, existing pipes, and catch basins. Use non-shrink grout when suitable gaskets are not available.

Service connection pipes are not to protrude into the main.

Pipes being crossed must be supported as shown in Standard Drawing 4-300.

## 5A.2 Manhole and Catch Basin Installation

Installation of manholes will conform to the following and Standard Drawings 3-100, 3-101, and 3-102. Installation of catch basins will conform to the following and Standard Drawings 5-100, 5-101, 5-200, 2-201 and 2-202

Concrete for benching and bases will be to ASTM A3000 Type HS high sulphate-resistant cement. Cast-in-place concrete will develop a compressive strength of not less than 32 MPa in 28 Days. Manhole and catch basin bases that are poured in place will be 200 mm thick and rest on undisturbed soil.

Both the inside and outside of each manhole and catch basin barrel joint will be finished smooth with non-shrink grout. Spacing of manhole steps is to be no more than 400 mm on center for full depth of manhole, and no more than 600 mm from the top step to the rim of the manhole. Steps are to be aligned with the frame and cover. Safety platforms are to be installed as per Standard Drawing 3-201 on manholes greater than 5.0 m in depth. Two (2) safety platforms are to be installed on manholes greater than 10.0 m in depth.

Openings for connections made in the field must not be greater than the outer diameter of the pipe by more than 50 mm in any direction, must not be closer than 225mm or one half of the larger pipe diameter (whichever is greater), and must be cored or cut. See Standard Drawing 3-207. Existing manhole floors will be rechanneled and properly benched, and the junction area will be grouted to form a smooth joint.

When pre-benched manholes aren't used, the benching will be placed by hand. Manhole benching will ensure good footing for workers and adequate space for minor tools and equipment. Benching will be sloped toward the channel at 1.0% (10 mm/m). The benching will provide a u-shaped channel as a continuation of the incoming pipe(s), with a side height of 0.75 times the full diameter of the sewer. Channelling and benching will be finished to trowel smoothness to provide an unobstructed flow. Branch lines entering the manhole will be channeled to join the main line at an acute angle. Sanitary service connections made directly to a manhole must extend to discharge directly to the channel within the manhole, not onto the benching. See Standard Drawing 7-106.

Set the frame and cover to the required elevation using no more than three concrete grade rings. Grade rings must be sealed either with non-shrink grout or RAM-NEK or approved equal.

Recess the catch basin frame and cover 10 mm below the concrete gutter elevation and 10 mm behind the concrete face of curb. Catch basin neck sections and catch basin frames must be installed within 50 mm of plumb with the catch basin shaft.

All frame and cover castings must be true to form and dimensions, free from faults, sponginess, cracks, blowholes, or other defects affecting their strength.

## 5A.3 Testing and Inspection

Trench backfill compaction will be tested as per Section 9.3. Sewers will be inspected and tested as per Section 9.5.

# Appendix 5B - DESIGN STORM TABLES

## 5B.1 4 Hour Chicago (Modified) Design Storm

| Time (Td) | | 2-yr | 5-yr | 10-yr | 25-yr | 50-yr | 100-yr |
|---|---|---|---|---|---|---|---|
| minutes | hours | | | | | | |
| 0 | 0.00 | 1.10 | 1.44 | 1.68 | 1.97 | 2.18 | 3.20 |
| 5 | 0.08 | 2.28 | 2.98 | 3.47 | 4.07 | 4.50 | 6.62 |
| 10 | 0.17 | 2.38 | 3.11 | 3.63 | 4.26 | 4.72 | 6.93 |
| 15 | 0.25 | 2.50 | 3.27 | 3.82 | 4.48 | 4.96 | 7.29 |
| 20 | 0.33 | 2.63 | 3.45 | 4.02 | 4.72 | 5.23 | 7.68 |
| 25 | 0.42 | 2.79 | 3.65 | 4.26 | 5.00 | 5.54 | 8.15 |
| 30 | 0.50 | 2.96 | 3.90 | 4.54 | 5.34 | 5.91 | 8.69 |
| 35 | 0.58 | 3.18 | 4.18 | 4.87 | 5.73 | 6.35 | 9.33 |
| 40 | 0.67 | 3.44 | 4.52 | 5.27 | 6.20 | 6.88 | 10.10 |
| 45 | 0.75 | 3.76 | 4.94 | 5.78 | 6.79 | 7.52 | 11.04 |
| 50 | 0.83 | 4.17 | 5.48 | 6.41 | 7.54 | 8.36 | 12.32 |
| 55 | 0.92 | 4.70 | 6.21 | 7.26 | 8.52 | 9.50 | 13.93 |
| 60 | 1.00 | 5.48 | 7.24 | 8.46 | 9.93 | 11.04 | 16.29 |
| 65 | 1.08 | 6.67 | 8.85 | 10.31 | 12.16 | 13.56 | 19.93 |
| 70 | 1.17 | 8.90 | 11.83 | 13.88 | 16.38 | 18.18 | 26.79 |
| 75 | 1.25 | 15.39 | 20.68 | 24.28 | 28.70 | 31.90 | 47.04 |
| 80 | 1.33 | 43.60 | 59.66 | 70.61 | 84.38 | 94.16 | 138.23 |
| 85 | 1.42 | 43.60 | 59.66 | 70.61 | 84.38 | 94.16 | 138.23 |
| 90 | 1.50 | 14.53 | 19.45 | 22.83 | 26.97 | 30.03 | 44.25 |
| 95 | 1.58 | 10.80 | 14.37 | 16.87 | 19.94 | 22.08 | 32.57 |
| 100 | 1.67 | 8.80 | 11.65 | 13.71 | 16.13 | 17.94 | 26.36 |
| 105 | 1.75 | 7.52 | 9.99 | 11.67 | 13.81 | 15.34 | 22.50 |
| 110 | 1.83 | 6.63 | 8.76 | 10.31 | 12.16 | 13.47 | 19.82 |
| 115 | 1.92 | 5.98 | 7.90 | 9.28 | 10.92 | 12.09 | 17.79 |
| 120 | 2.00 | 5.46 | 7.22 | 8.44 | 9.93 | 11.04 | 16.18 |
| 125 | 2.08 | 5.05 | 6.66 | 7.79 | 9.18 | 10.15 | 15.00 |
| 130 | 2.17 | 4.70 | 6.20 | 7.24 | 8.52 | 9.42 | 13.93 |
| 135 | 2.25 | 4.41 | 5.81 | 6.79 | 8.02 | 8.85 | 13.07 |
| 140 | 2.33 | 4.16 | 5.48 | 6.41 | 7.54 | 8.36 | 12.32 |
| 145 | 2.42 | 3.95 | 5.20 | 6.06 | 7.13 | 7.91 | 11.57 |
| 150 | 2.50 | 3.76 | 4.94 | 5.77 | 6.78 | 7.52 | 11.04 |
| 155 | 2.58 | 3.59 | 4.71 | 5.50 | 6.48 | 7.18 | 10.54 |
| 160 | 2.67 | 3.44 | 4.52 | 5.27 | 6.20 | 6.87 | 10.09 |
| 165 | 2.75 | 3.30 | 4.34 | 5.06 | 5.96 | 6.59 | 9.70 |
| 170 | 2.83 | 3.18 | 4.18 | 4.87 | 5.72 | 6.35 | 9.32 |
| 175 | 2.92 | 3.07 | 4.03 | 4.70 | 5.53 | 6.12 | 8.99 |
| 180 | 3.00 | 2.96 | 3.89 | 4.54 | 5.34 | 5.91 | 8.69 |
| 185 | 3.08 | 2.88 | 3.77 | 4.40 | 5.16 | 5.72 | 8.40 |
| 190 | 3.17 | 2.78 | 3.65 | 4.26 | 5.00 | 5.54 | 8.14 |
| 195 | 3.25 | 2.71 | 3.55 | 4.14 | 4.86 | 5.38 | 7.91 |
| 200 | 3.33 | 2.63 | 3.45 | 4.02 | 4.72 | 5.23 | 7.68 |
| 205 | 3.42 | 2.56 | 3.36 | 3.91 | 4.59 | 5.09 | 7.48 |
| 210 | 3.50 | 2.50 | 3.27 | 3.81 | 4.48 | 4.96 | 7.29 |
| 215 | 3.58 | 2.44 | 3.19 | 3.71 | 4.37 | 4.83 | 7.10 |

| Time (Td) | | 2-yr | 5-yr | 10-yr | 25-yr | 50-yr | 100-yr |
|---|---|---|---|---|---|---|---|
| minutes | hours | | | | | | |
| 220 | 3.67 | 2.38 | 3.11 | 3.63 | 4.26 | 4.72 | 6.93 |
| 225 | 3.75 | 2.32 | 3.04 | 3.54 | 4.16 | 4.61 | 6.77 |
| 230 | 3.83 | 2.28 | 2.97 | 3.47 | 4.07 | 4.50 | 6.61 |
| 235 | 3.92 | 2.23 | 2.91 | 3.39 | 3.98 | 4.41 | 6.47 |
| 240 | 4.00 | 1.10 | 1.44 | 1.67 | 1.96 | 2.17 | 3.18 |

## 5B.2 24 Hour Huff Distribution

| Time (Td) | | 2-yr | 5-yr | 10-yr | 25-yr | 50-yr | 100-yr |
|---|---|---|---|---|---|---|---|
| minutes | hours | | | | | | |
| 0 | 0 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 15 | 0.25 | 0.26 | 0.36 | 0.42 | 0.51 | 0.57 | 0.82 |
| 30 | 0.5 | 0.52 | 0.72 | 0.85 | 1.01 | 1.13 | 1.63 |
| 45 | 0.75 | 0.79 | 1.08 | 1.27 | 1.52 | 1.70 | 2.44 |
| 60 | 1 | 1.05 | 1.44 | 1.69 | 2.02 | 2.26 | 3.27 |
| 75 | 1.25 | 1.40 | 1.92 | 2.25 | 2.70 | 3.02 | 4.35 |
| 90 | 1.5 | 2.10 | 2.88 | 3.39 | 4.04 | 4.52 | 6.53 |
| 105 | 1.75 | 2.79 | 3.84 | 4.51 | 5.40 | 6.03 | 8.73 |
| 120 | 2 | 3.50 | 4.80 | 5.64 | 6.74 | 7.54 | 10.89 |
| 135 | 2.25 | 4.20 | 5.77 | 6.77 | 8.09 | 9.08 | 13.04 |
| 150 | 2.5 | 4.67 | 6.41 | 7.51 | 9.03 | 10.08 | 14.51 |
| 165 | 2.75 | 4.79 | 6.58 | 7.72 | 9.23 | 10.34 | 14.95 |
| 180 | 3 | 4.91 | 6.75 | 7.92 | 9.50 | 10.61 | 15.29 |
| 195 | 3.25 | 5.04 | 6.93 | 8.13 | 9.70 | 10.88 | 15.72 |
| 210 | 3.5 | 5.16 | 7.13 | 8.33 | 9.97 | 11.15 | 16.07 |
| 225 | 3.75 | 5.09 | 6.99 | 8.20 | 9.84 | 11.01 | 15.81 |
| 240 | 4 | 4.88 | 6.70 | 7.85 | 9.43 | 10.54 | 15.20 |
| 255 | 4.25 | 4.67 | 6.41 | 7.51 | 8.96 | 10.08 | 14.51 |
| 270 | 4.5 | 4.45 | 6.12 | 7.17 | 8.56 | 9.61 | 13.82 |
| 285 | 4.75 | 4.24 | 5.82 | 6.83 | 8.15 | 9.14 | 13.22 |
| 300 | 5 | 4.02 | 5.51 | 6.48 | 7.75 | 8.68 | 12.53 |
| 315 | 5.25 | 3.79 | 5.21 | 6.11 | 7.34 | 8.21 | 11.84 |
| 330 | 5.5 | 3.57 | 4.90 | 5.75 | 6.87 | 7.67 | 11.06 |
| 345 | 5.75 | 3.34 | 4.59 | 5.39 | 6.44 | 7.21 | 10.37 |
| 360 | 6 | 3.12 | 4.28 | 5.03 | 6.01 | 6.74 | 9.68 |
| 375 | 6.25 | 2.93 | 4.03 | 4.73 | 5.65 | 6.32 | 9.16 |
| 390 | 6.5 | 2.74 | 3.77 | 4.43 | 5.29 | 5.92 | 8.54 |
| 405 | 6.75 | 2.55 | 3.51 | 4.12 | 4.93 | 5.51 | 7.95 |
| 420 | 7 | 2.37 | 3.25 | 3.82 | 4.57 | 5.11 | 7.37 |
| 435 | 7.25 | 2.19 | 3.01 | 3.53 | 4.22 | 4.72 | 6.82 |
| 450 | 7.5 | 2.06 | 2.82 | 3.31 | 3.96 | 4.43 | 6.38 |
| 465 | 7.75 | 1.92 | 2.64 | 3.09 | 3.69 | 4.13 | 5.96 |
| 480 | 8 | 1.78 | 2.45 | 2.87 | 3.43 | 3.84 | 5.54 |
| 495 | 8.25 | 1.64 | 2.26 | 2.65 | 3.17 | 3.54 | 5.11 |
| 510 | 8.5 | 1.54 | 2.11 | 2.48 | 2.96 | 3.32 | 4.78 |
| 525 | 8.75 | 1.48 | 2.03 | 2.39 | 2.86 | 3.20 | 4.60 |
| 540 | 9 | 1.43 | 1.96 | 2.29 | 2.75 | 3.07 | 4.43 |
| 555 | 9.25 | 1.37 | 1.88 | 2.21 | 2.64 | 2.95 | 4.26 |

| Time (Td) | | 2-yr | 5-yr | 10-yr | 25-yr | 50-yr | 100-yr |
|---|---|---|---|---|---|---|---|
| minutes | hours | | | | | | |
| 570 | 9.5 | 1.31 | 1.80 | 2.12 | 2.53 | 2.83 | 4.08 |
| 585 | 9.75 | 1.26 | 1.73 | 2.03 | 2.43 | 2.71 | 3.91 |
| 600 | 10 | 1.20 | 1.65 | 1.94 | 2.32 | 2.60 | 3.74 |
| 615 | 10.25 | 1.15 | 1.58 | 1.85 | 2.22 | 2.48 | 3.57 |
| 630 | 10.5 | 1.10 | 1.50 | 1.76 | 2.11 | 2.36 | 3.40 |
| 645 | 10.75 | 1.04 | 1.43 | 1.67 | 2.00 | 2.24 | 3.23 |
| 660 | 11 | 0.99 | 1.36 | 1.60 | 1.91 | 2.14 | 3.08 |
| 675 | 11.25 | 0.94 | 1.29 | 1.52 | 1.82 | 2.04 | 2.93 |
| 690 | 11.5 | 0.89 | 1.23 | 1.44 | 1.72 | 1.93 | 2.78 |
| 705 | 11.75 | 0.85 | 1.17 | 1.37 | 1.63 | 1.83 | 2.63 |
| 720 | 12 | 0.80 | 1.10 | 1.29 | 1.54 | 1.73 | 2.49 |
| 735 | 12.25 | 0.78 | 1.06 | 1.24 | 1.49 | 1.67 | 2.40 |
| 750 | 12.5 | 0.75 | 1.02 | 1.20 | 1.44 | 1.61 | 2.32 |
| 765 | 12.75 | 0.72 | 0.99 | 1.16 | 1.38 | 1.55 | 2.24 |
| 780 | 13 | 0.69 | 0.95 | 1.11 | 1.33 | 1.49 | 2.15 |
| 795 | 13.25 | 0.66 | 0.91 | 1.07 | 1.28 | 1.43 | 2.06 |
| 810 | 13.5 | 0.63 | 0.87 | 1.02 | 1.23 | 1.37 | 1.97 |
| 825 | 13.75 | 0.61 | 0.83 | 0.98 | 1.17 | 1.31 | 1.88 |
| 840 | 14 | 0.58 | 0.79 | 0.93 | 1.11 | 1.24 | 1.80 |
| 855 | 14.25 | 0.55 | 0.75 | 0.88 | 1.06 | 1.18 | 1.70 |
| 870 | 14.5 | 0.53 | 0.73 | 0.85 | 1.02 | 1.13 | 1.64 |
| 885 | 14.75 | 0.52 | 0.71 | 0.84 | 1.00 | 1.12 | 1.62 |
| 900 | 15 | 0.51 | 0.71 | 0.83 | 0.99 | 1.11 | 1.60 |
| 915 | 15.25 | 0.51 | 0.70 | 0.82 | 0.98 | 1.09 | 1.58 |
| 930 | 15.5 | 0.50 | 0.69 | 0.81 | 0.96 | 1.08 | 1.56 |
| 945 | 15.75 | 0.49 | 0.68 | 0.80 | 0.96 | 1.07 | 1.54 |
| 960 | 16 | 0.49 | 0.67 | 0.79 | 0.94 | 1.05 | 1.52 |
| 975 | 16.25 | 0.48 | 0.66 | 0.78 | 0.93 | 1.04 | 1.50 |
| 990 | 16.5 | 0.48 | 0.66 | 0.77 | 0.92 | 1.03 | 1.49 |
| 1005 | 16.75 | 0.47 | 0.65 | 0.76 | 0.91 | 1.01 | 1.47 |
| 1020 | 17 | 0.47 | 0.64 | 0.75 | 0.90 | 1.00 | 1.45 |
| 1035 | 17.25 | 0.46 | 0.63 | 0.74 | 0.88 | 0.99 | 1.43 |
| 1050 | 17.5 | 0.45 | 0.62 | 0.73 | 0.88 | 0.97 | 1.41 |
| 1065 | 17.75 | 0.45 | 0.61 | 0.72 | 0.86 | 0.96 | 1.39 |
| 1080 | 18 | 0.44 | 0.61 | 0.71 | 0.85 | 0.95 | 1.37 |
| 1095 | 18.25 | 0.43 | 0.60 | 0.70 | 0.84 | 0.93 | 1.35 |
| 1110 | 18.5 | 0.43 | 0.59 | 0.69 | 0.83 | 0.93 | 1.33 |
| 1125 | 18.75 | 0.42 | 0.58 | 0.68 | 0.82 | 0.91 | 1.31 |
| 1140 | 19 | 0.42 | 0.57 | 0.67 | 0.80 | 0.90 | 1.30 |
| 1155 | 19.25 | 0.41 | 0.56 | 0.66 | 0.79 | 0.88 | 1.27 |
| 1170 | 19.5 | 0.39 | 0.54 | 0.63 | 0.75 | 0.85 | 1.23 |
| 1185 | 19.75 | 0.38 | 0.52 | 0.61 | 0.73 | 0.81 | 1.17 |
| 1200 | 20 | 0.36 | 0.50 | 0.58 | 0.70 | 0.78 | 1.13 |
| 1215 | 20.25 | 0.35 | 0.48 | 0.56 | 0.67 | 0.75 | 1.08 |
| 1230 | 20.5 | 0.33 | 0.46 | 0.54 | 0.65 | 0.72 | 1.05 |
| 1245 | 20.75 | 0.33 | 0.45 | 0.53 | 0.63 | 0.71 | 1.02 |
| 1260 | 21 | 0.32 | 0.44 | 0.51 | 0.62 | 0.69 | 0.99 |

| Time (Td) | | 2-yr | 5-yr | 10-yr | 25-yr | 50-yr | 100-yr |
|---|---|---|---|---|---|---|---|
| minutes | hours | | | | | | |
| 1275 | 21.25 | 0.31 | 0.43 | 0.50 | 0.60 | 0.67 | 0.97 |
| 1290 | 21.5 | 0.30 | 0.42 | 0.49 | 0.58 | 0.65 | 0.94 |
| 1305 | 21.75 | 0.29 | 0.40 | 0.47 | 0.56 | 0.63 | 0.91 |
| 1320 | 22 | 0.28 | 0.38 | 0.45 | 0.54 | 0.60 | 0.87 |
| 1335 | 22.25 | 0.27 | 0.37 | 0.43 | 0.52 | 0.58 | 0.83 |
| 1350 | 22.5 | 0.25 | 0.35 | 0.41 | 0.49 | 0.55 | 0.79 |
| 1365 | 22.75 | 0.24 | 0.33 | 0.39 | 0.47 | 0.52 | 0.75 |
| 1380 | 23 | 0.23 | 0.32 | 0.37 | 0.44 | 0.50 | 0.72 |
| 1395 | 23.25 | 0.22 | 0.30 | 0.35 | 0.42 | 0.47 | 0.68 |
| 1410 | 23.5 | 0.20 | 0.28 | 0.33 | 0.39 | 0.44 | 0.64 |
| 1425 | 23.75 | 0.19 | 0.26 | 0.31 | 0.37 | 0.42 | 0.60 |
| 1440 | 24 | 0.18 | 0.25 | 0.29 | 0.35 | 0.39 | 0.56 |

## 5B.3 IDF Curves (Rainfall Intensity in mm/hr)

| Time (Td) | | 2-yr | 5-yr | 10-yr | 25-yr | 50-yr | 100-yr |
|---|---|---|---|---|---|---|---|
| min | hours | | | | | | |
| 5 | 0.08 | 81 | 126 | 152 | 190 | 207 | 231 |
| 6 | 0.10 | 74.8 | 115 | 139 | 173 | 189 | 219 |
| 7 | 0.12 | 69.6 | 106 | 129 | 159 | 175 | 208 |
| 8 | 0.13 | 65.2 | 98.8 | 120 | 148 | 163 | 199 |
| 9 | 0.15 | 61.3 | 92.4 | 112 | 138 | 152 | 190 |
| 10 | 0.17 | 57.9 | 86.8 | 105 | 130 | 143 | 182 |
| 11 | 0.18 | 54.9 | 82 | 100 | 122 | 135 | 175 |
| 12 | 0.20 | 52.2 | 77.7 | 94.4 | 116 | 128 | 168 |
| 13 | 0.22 | 49.8 | 73.9 | 89.8 | 110 | 122 | 162 |
| 14 | 0.23 | 47.7 | 70.4 | 85.7 | 105 | 116 | 157 |
| 15 | 0.25 | 45.7 | 67.4 | 82 | 100 | 111 | 151 |
| 16 | 0.27 | 43.9 | 64.6 | 78.6 | 95.9 | 106 | 146 |
| 17 | 0.28 | 42.3 | 62 | 75.5 | 92.1 | 102 | 142 |
| 18 | 0.3 | 40.8 | 59.7 | 72.6 | 88.5 | 98.3 | 138 |
| 19 | 0.32 | 39.4 | 57.5 | 70 | 85.3 | 94.7 | 134 |
| 20 | 0.33 | 38.1 | 55.5 | 67.6 | 82.3 | 91.4 | 130 |
| 21 | 0.35 | 36.9 | 53.7 | 65.4 | 79.5 | 88.4 | 126 |
| 22 | 0.37 | 35.7 | 52 | 63.3 | 77 | 85.6 | 123 |
| 23 | 0.38 | 34.7 | 50.4 | 61.4 | 74.6 | 83 | 120 |
| 24 | 0.40 | 33.7 | 48.9 | 59.6 | 72.3 | 80.5 | 117 |
| 25 | 0.42 | 32.8 | 47.5 | 57.9 | 70.3 | 78.2 | 114 |
| 26 | 0.43 | 31.9 | 46.2 | 56.3 | 68.3 | 76 | 111 |
| 27 | 0.45 | 31.1 | 45 | 54.8 | 66.5 | 74 | 109 |
| 28 | 0.47 | 30.3 | 43.8 | 53.4 | 64.7 | 72.1 | 106 |
| 29 | 0.48 | 29.6 | 42.7 | 52 | 63.1 | 70.3 | 104 |
| 30 | 0.50 | 28.9 | 41.7 | 50.8 | 61.5 | 68.6 | 102 |
| 31 | 0.52 | 28.3 | 40.7 | 49.6 | 60.1 | 67 | 100 |
| 32 | 0.53 | 27.6 | 39.8 | 48.4 | 58.7 | 65.4 | 97.6 |
| 33 | 0.55 | 27 | 38.9 | 47.4 | 57.3 | 64 | 95.7 |
| 34 | 0.57 | 26.5 | 38.1 | 46.3 | 56.1 | 62.6 | 93.9 |
| 35 | 0.58 | 25.9 | 37.3 | 45.4 | 54.9 | 61.2 | 92.1 |

| Time (Td) | | 2-yr | 5-yr | 10-yr | 25-yr | 50-yr | 100-yr |
|---|---|---|---|---|---|---|---|
| min | hours | | | | | | |
| 36 | 0.60 | 25.4 | 36.5 | 44.4 | 53.8 | 60 | 90.4 |
| 37 | 0.62 | 24.9 | 35.8 | 43.5 | 52.7 | 58.8 | 88.7 |
| 38 | 0.63 | 24.5 | 35.1 | 42.7 | 51.6 | 57.6 | 87.2 |
| 39 | 0.65 | 24 | 34.4 | 41.9 | 50.6 | 56.5 | 85.6 |
| 40 | 0.67 | 23.6 | 33.8 | 41.1 | 49.7 | 55.4 | 84.2 |
| 41 | 0.68 | 23.1 | 33.1 | 40.3 | 48.7 | 54.4 | 82.8 |
| 42 | 0.70 | 22.7 | 32.6 | 39.6 | 47.9 | 53.5 | 81.4 |
| 43 | 0.72 | 22.4 | 32 | 38.9 | 47 | 52.5 | 80.1 |
| 44 | 0.73 | 22 | 31.4 | 38.2 | 46.2 | 51.6 | 78.8 |
| 45 | 0.75 | 21.6 | 30.9 | 37.6 | 45.4 | 50.7 | 77.6 |
| 46 | 0.77 | 21.3 | 30.4 | 37 | 44.7 | 49.9 | 76.4 |
| 47 | 0.78 | 20.9 | 29.9 | 36.4 | 43.9 | 49.1 | 75.3 |
| 48 | 0.80 | 20.6 | 29.4 | 35.8 | 43.2 | 48.3 | 74.2 |
| 49 | 0.82 | 20.3 | 29 | 35.3 | 42.6 | 47.6 | 73.1 |
| 50 | 0.83 | 20 | 28.6 | 34.7 | 41.9 | 46.8 | 72 |
| 51 | 0.85 | 19.7 | 28.1 | 34.2 | 41.3 | 46.1 | 71 |
| 52 | 0.87 | 19.4 | 27.7 | 33.7 | 40.7 | 45.5 | 70 |
| 53 | 0.88 | 19.2 | 27.3 | 33.2 | 40.1 | 44.8 | 69.1 |
| 54 | 0.90 | 18.9 | 26.9 | 32.7 | 39.5 | 44.2 | 68.2 |
| 55 | 0.92 | 18.6 | 26.6 | 32.3 | 38.9 | 43.6 | 67.3 |
| 56 | 0.93 | 18.4 | 26.2 | 31.8 | 38.4 | 43 | 66.4 |
| 57 | 0.95 | 18.2 | 25.9 | 31.4 | 37.9 | 42.4 | 65.5 |
| 58 | 0.97 | 17.9 | 25.5 | 31 | 37.4 | 41.8 | 64.7 |
| 59 | 0.98 | 17.7 | 25.2 | 30.6 | 36.9 | 41.3 | 63.9 |
| 60 | 1.00 | 17.5 | 24.9 | 30.2 | 36.4 | 40.7 | 63.1 |
| 65 | 1.08 | 16.4 | 23.4 | 28.4 | 34.2 | 38.3 | 59.5 |
| 70 | 1.17 | 15.5 | 22.1 | 26.8 | 32.3 | 36.1 | 56.3 |
| 75 | 1.25 | 14.8 | 20.9 | 25.4 | 30.6 | 34.3 | 53.4 |
| 80 | 1.33 | 14 | 19.9 | 24.2 | 29.1 | 32.6 | 50.9 |
| 85 | 1.42 | 13.4 | 19 | 23 | 27.7 | 31.1 | 48.6 |
| 90 | 1.50 | 12.8 | 18.2 | 22 | 26.5 | 29.7 | 46.5 |
| 95 | 1.58 | 12.3 | 17.4 | 21.1 | 25.4 | 28.5 | 44.5 |
| 100 | 1.67 | 11.8 | 16.7 | 20.3 | 24.4 | 27.3 | 42.8 |
| 105 | 1.75 | 11.4 | 16.1 | 19.5 | 23.5 | 26.3 | 41.2 |
| 110 | 1.83 | 11 | 15.5 | 18.8 | 22.6 | 25.3 | 39.7 |
| 115 | 1.92 | 10.6 | 15 | 18.1 | 21.8 | 24.5 | 38.3 |
| 120 | 2 | 10.3 | 14.5 | 17.5 | 21.1 | 23.7 | 37 |
| 180 | 3 | 7.47 | 10.5 | 12.7 | 15.3 | 17.1 | 26.7 |
| 240 | 4 | 5.95 | 8.37 | 10.1 | 12.1 | 13.6 | 21 |
| 300 | 5 | 4.98 | 7.01 | 8.41 | 10.1 | 11.3 | 17.5 |
| 360 | 6 | 4.31 | 6.05 | 7.25 | 8.71 | 9.77 | 15 |
| 420 | 7 | 3.81 | 5.35 | 6.4 | 7.68 | 8.62 | 13.1 |
| 480 | 8 | 3.42 | 4.81 | 5.74 | 6.89 | 7.74 | 11.7 |
| 540 | 9 | 3.11 | 4.37 | 5.22 | 6.26 | 7.03 | 10.6 |
| 600 | 10 | 2.86 | 4.02 | 4.79 | 5.74 | 6.45 | 9.7 |
| 660 | 11 | 2.65 | 3.72 | 4.43 | 5.32 | 5.97 | 8.94 |
| 720 | 12 | 2.47 | 3.47 | 4.13 | 4.95 | 5.56 | 8.3 |
| 780 | 13 | 2.31 | 3.25 | 3.87 | 4.64 | 5.21 | 7.75 |

| Time (Td) | | 2-yr | 5-yr | 10-yr | 25-yr | 50-yr | 100-yr |
|---|---|---|---|---|---|---|---|
| min | hours | | | | | | |
| 840 | 14 | 2.18 | 3.06 | 3.64 | 4.37 | 4.9 | 7.27 |
| 900 | 15 | 2.06 | 2.9 | 3.44 | 4.13 | 4.63 | 6.85 |
| 960 | 16 | 1.96 | 2.75 | 3.26 | 3.91 | 4.4 | 6.48 |
| 1020 | 17 | 1.86 | 2.62 | 3.1 | 3.73 | 4.18 | 6.16 |
| 1080 | 18 | 1.78 | 2.5 | 2.96 | 3.56 | 3.99 | 5.86 |
| 1140 | 19 | 1.7 | 2.39 | 2.84 | 3.4 | 3.82 | 5.59 |
| 1200 | 20 | 1.64 | 2.3 | 2.72 | 3.26 | 3.66 | 5.35 |
| 1260 | 21 | 1.57 | 2.21 | 2.61 | 3.13 | 3.52 | 5.13 |
| 1320 | 22 | 1.51 | 2.13 | 2.52 | 3.02 | 3.39 | 4.93 |
| 1380 | 23 | 1.46 | 2.05 | 2.43 | 2.91 | 3.27 | 4.74 |
| 1440 | 24 | 1.41 | 1.98 | 2.34 | 2.81 | 3.16 | 4.57 |

# Appendix 5C - STORMWATER STORAGE DESIGN

## 5C.1 Modelling Criteria

### 5C.1.1 Continuous Simulation

Continuous simulation is required to model urban runoff water quality from all wet ponds and wetlands to estimate overall sediment removal rates. It is important that reasonable input parameters be used in the simulation. Currently, little calibration information is available to verify the accuracy of the parameters.

### 5C.1.2 Particle Sizes and Settling Velocities

It is necessary to consider the particle size distribution for soils and their settling velocities. Although the relative distribution of the particles is seasonal, and dependent on location, a general distribution should be used for modelling purposes.

To estimate the total suspended solids (TSS) removal rate from wet ponds, wetlands, and other devices or technologies requiring sediment removal (e.g. oil/grit separators), Tables 5C.1 and 5C.2 should be used as input into the model.

**Table 5C.1 – Particle Size and Setting Velocities for Sediment Removal – Permanent Pool**

| Size Range (µm) | Density (kg/m$^3$) | Fraction (%) | Cumulative Total (%) | Settling Velocity (m/s) |
|---|---|---|---|---|
| < 10 | 1500 | 23 | 23 | 0.00000592 |
| 10-20 | 2000 | 9 | 32 | 0.00004730 |
| 20-50 | 2500 | 13 | 45 | 0.00028300 |
| 50-150 | 2650 | 23 | 68 | 0.00195000 |
| > 150 | 2650 | 32 | 100 | 0.01240000 |

**Notes:**

a) Densities are estimated.
b) Settling velocities are based on 15 degree Celsius temperature.
c) Settling velocities are based on the lower end of the size range.
d) A size of 5 µm is used for the <10 µm size range.

**Table 5C.2 – Particle Size and Setting Velocities for Sediment Removal – Forebay**

| Particle Size (µm) | Density (kg/m$^3$) | Size Range (µm) | Fraction (%) | Settling Velocity (m/s) |
|---|---|---|---|---|
| 50 | 2650 | > 50 | 55 | 0.00195 |
| 75 | 2650 | > 75 | 46 | 0.00438 |
| 150 | 2650 | > 150 | 32 | 0.01240 |

**Notes:**

a) The particle size distribution follows the New Jersey Department of Environmental Protection curve. This curve, which reflects the presence of more fine particles than originally assumed, falls within the wide range of particle size data acquired.
b) The settling velocities are largely based on Stokes Equation or Newton's Law of settling for larger particles. This reflects the findings by Sansalone and others.

### 5C.1.3 Rate of Sediment Accumulation

The rate of sediment accumulation must be used in the modelling to verify the sediment storage capacity of the forebay. The forebay must be able to accommodate the amassed sediment for a minimum of 25 years. Refer to Section 5C.3.2 for more information.

Based on a study undertaken in 1992 by J.N. MacKenzie Engineering Ltd. for QUALHYMO and QHM:

- The washoff method should be 2, with washoff rates of 6,000 and 3,000 grams per cubic metre, for impervious and pervious areas respectively, and a washoff coefficient equal to 1.20; and
- The pollutant build-up method should be 1, representing a power linear build-up method. The equivalent initial accumulation is 30 days, maximum accumulation is 0.20 kg per ha, and build-up equals 0.00055 kg per square metre per day.

## 5C.2 Water Quality

All wet ponds are required to provide enhanced water quality. Wet ponds are to be sized to provide a minimum 85% removal of TSS for particle sizes greater than, or equal to, 50 µm.

At a minimum, the permanent pool (pond bottom to NWL) must be sized for a volume equal to 25 mm over the entire contributing drainage area times the overall catchment imperviousness ratio (25 mm x catchment area x overall catchment imperviousness ratio). A minimum detention time of 24 hours must also be provided.

Water quality monitoring might be required during the maintenance period. Costs of the program are to be covered by the Developer during the maintenance period.

## 5C.3 Sediment Forebay

A sediment forebay facilitates maintenance and improves pollutant removal of larger particles near the inlet of the pond. The forebay should be one of the deeper areas of the pond to minimize the potential for particle re-suspension.

Sediment forebays are required on all wet ponds. The forebay can be included within the wet pond area or as a separate facility. As well, each inlet location must have a forebay. The forebay area should not exceed one third of the total permanent pond surface area.

### 5C.3.1 Short-Circuiting

To avoid short-circuiting and to ensure that sediment will have sufficient time to settle out in the forebay, minimize the number of inlets into a pond and/or ensure that flow path length(s) are maximized. The resulting effective length to width ratio in the forebay should be 4:1 to 5:1, with a minimum ratio of 3:1. The length and width should reflect the anticipated actual flow path and are measured at the NWL; typically, the length is measured from the exit of the inlet to the toe of the forebay berm (refer to Standard Drawing 5-501). Three dimensional modelling with programs such as Computational Fluid Dynamics (CFD) can be used to determine flow and velocity patterns, as well as sedimentation patterns.

### 5C.3.2 Sizing

Sizing of the forebay depends on the inlet configuration. There are several calculations that need to be made to ensure that it is adequately sized. A target particle size of 150 µm should be used for wet ponds. Where possible, the sediment forebay should be sized to accommodate the amassed sediment for a minimum period of 25 years without affecting treatment capacity; this is to minimize the frequency of major cleaning.

The treatment capacity is considered maintained as long as the theoretical sediment accumulation, computed using the following equation, is at least 0.30 m below the invert of the incoming storm pipe:

$$SSCR=25 \times RV \times \frac{TSSconc}{1000} \times BF \times PSDF$$

Where:

| | | | |
|---|---|---|---|
| SSCR = | sediment storage capacity required in kg | | |
| 25 = | multiplication factor for 25 years of sediment storage | | |
| RV = | computed average annual runoff volume ($m^3$) | | |
| TSSconc = | TSS concentration by land use (mg/L): | | |
| | | Commercial = | 180 |
| | | Industrial = | 369 |
| | | On-going Development = | 1896 |
| | | Residential = | 444 |
| BF = | bed load multiplication factor (typically 2) | | |
| PSDF = | particle size distribution factor from Table 5C.2 | | |

### 5C.3.3 Settling Length

The following equation defines the appropriate forebay length for a given settling velocity and hence particle size to be trapped in the forebay. Refer to Table 5C.2 for particle sizes and settling velocities. For wet ponds a particle size of 150 µm should be used; for wetlands a particle size of 75 µm should be used.

$$Length=\left(\frac{rQ_p}{V_s}\right)^{0.5}$$

Where:

| | |
|---|---|
| Length = | forebay length in m |
| r = | length to width ratio of forebay |
| $Q_p$ = | peak inlet flow rate for a 1:5 year event in $m^3/s$ |
| $V_s$ = | settling velocity in m/s |

### 5C.3.4 Dispersion Length

A check of the entire forebay cross-sectional area should ensure that the average velocity in the forebay is less than, or equal to, 0.15 m/s. This velocity (0.15 m/s) is the maximum permissible velocity before which erosion will occur in a channel.

Typically, the dispersion length is smaller than the settling length unless there is a large upstream drainage area or the pond is subject to large inflows. When this occurs, the pipe design capacity should be used. In all cases, the forebay length (designated Length) should be greater than, or equal to, the larger of the two forebay lengths given by the settling length above and the dispersion length below.

$$Length=\frac{8Q}{dV_f}$$

Where:

| | |
|---|---|
| Length = | length of dispersion in m |
| Q = | Inlet flow rate for a 1:5 year event in $m^3/s$ |
| d = | depth of the permanent pool in the forebay in m |
| $V_f$ = | desired velocity in the forebay in m/s<br>A value ≤ 0.50 m/s should be used |

The depth of the permanent pool in the forebay (d) reflects the deep section of the forebay required to minimize re-suspension and scour.

### 5C.3.5 Width

The minimum bottom width of the deep zone in the forebay is calculated by using the largest Length derived from the settling length and dispersion length calculations, divided by eight (8).

## 5C.4 Forebay Berm

An earthen berm should be used to separate the forebay from the rest of the pond. The top of the berm must be submerged a minimum of 0.30 m below the NWL. A submerged berm provides a safety benefit to the public (provides a barrier to the public walking along the berm) and allows vegetation to be planted around and along the berm. Sections of the forebay berm can be above the NWL, provided that they are protected against erosion when the berm overtops and is well vegetated in a way that inhibits public access. An opening at least 3.5 m in width with no vegetation or raised sections must be provided for boat access to the permanent pool of the pond.

The berm should be constructed with a solid substrate to facilitate removal of accumulated sediment and debris. In addition, the core of the berm must be impermeable and the berm itself geotechnically stable under submerged conditions. Sloughing of the berm must be greater than, or equal to, 150 mm at the time of FAC.

Emergent vegetation should be planted along the berm to promote filtration of water as it passes over. The plants should be established on the top and sides of the berm at a maximum planting depth of 30 cm.

If only the forebay is to be pumped out or drawn down during maintenance, the forebay berm must be designed as an impermeable small dam since the rest of the pond will not be drained. Care must be taken not to compromise the structural integrity of the berm or liner during drawdown conditions.

## 5C.5 Length:Width Ratio

The overall performance of the pond is influenced by the flow path through the pond. Problems encountered with earlier pond designs include construction of the outlet too close to the inlet and having multiple inlets at opposing ends of the pond based on servicing convenience. In both cases, short-circuiting reduces the effective volume of the facility.

Where possible, all stormwater servicing should be conveyed to one inlet location. To provide the longest flow path though the pond, the inlet should be located as far away from the outlet as possible. A pond with a minimum length to width ratio greater than, or equal to, 3:1 will generally have an acceptable flow path. The length and width should reflect the anticipated actual flow path and are measured at the NWL. The preferred length to width ratio ranges from 4:1 to 5:1. A ratio outside of this range requires the approval of the City. Effective length excludes forebay length.

The provision of additional berms or flow baffles in the pond to redirect flows and lengthen the flow path is also acceptable to ensure that short-circuiting will not occur.

The use of hydrodynamic models is recommended to assess flow, velocity, and sedimentation patterns.

## 5C.6 Pond Depth

The depths of the permanent and active storage areas are based on a variety of criteria, including potential stratification, the tolerance of plants to fluctuating water levels, and safety.

### 5C.6.1 Permanent Storage Areas

The minimum depth from the pond bottom to NWL must be 2.0 m, with the recommended depth being 2.50 m. A depth of 2.50 m minimizes aquatic growth in the pond and maximizes recreational potential.

A maximum depth of 3.0 m should not be exceeded. Depths in excess of 3.0 m require approval from the City. Although ponds deeper than 3.0 m may have benefits in terms of temperature, stratification is more likely, resulting in anoxic conditions which release metals and organics from the pond sediments.

### 5C.6.2 Active Storage Area

The active storage depth is defined as the depth between NWL and HWL. The active storage depth must be no greater than 2.0 m. Depths in excess of 2.0 m require approval from the City. In addition, a minimum freeboard of 0.30 m is required above the water level in the pond that corresponds to the design capacity of the overland emergency escape route.

The freeboard elevation is the minimum elevation along the perimeter of a pond or wetland that ensures safe operation without negative impact to adjacent or downstream property. The property line elevation for all properties along the perimeter of the pond should be above the freeboard elevation, unless a berm is provided along the perimeter of the pond to safeguard lower properties. In addition, the top of the outlet control structure (including access/maintenance roads), any associated electronic equipment, and any safety benches along the perimeter of the pond must be at or above the freeboard elevation.

## 5C.7 Overland Drainage and Escape Routes

In general, the design capacity of the overland emergency escape route from the pond will be the greater of:

- The resulting spillover rate for a 24 hour, 1:100 year event, assuming that the regular outflow is 0 $m^3$/s and the starting water level is equal to the pond bottom (dry ponds), or NWL (wet ponds); or
- 1.0 $m^3$/s.

The magnitude of the design capacity of the overland escape route must be determined at the time of pond design. The configuration and capacity must be adequate to convey the design capacity without creating unsafe conditions or negatively impacting downstream property. Assessment of the overland emergency escape route must extend to the location where the spilling flow will enter a downstream pond or drainage course that has a capacity exceeding that of the overland emergency escape route. Proper engineering design based on local circumstances is required.

Erosion Control needs must be evaluated for both the overland drainage routes into the pond and the overland emergency escape route from the pond.

## 5C.8 Landscaping and Vegetation

A planting strategy is required to provide shading, aesthetics, safety, enhanced pollutant removal, and waterfowl control. The purpose of the planting is to provide a sustainable community with naturalized treatment. Plants native to the Lloydminster region should be used where possible. Planting density may not have to be high, since natural succession will ultimately make up the vegetation. As well, the overall planting should be designed to minimize maintenance.

### 5C.8.1 Shallow Water Areas

Shallow water areas are considered to be the areas of the permanent pool where the depth is greater than, or equal to, 0.50 m. This is usually defined as the perimeter of the pond.

The selection of vegetation should consider nutrient uptake, stormwater filtration, safety, and aesthetics. Benefits include the prevention of re-suspension of bottom sediments and the reduction of flow velocities to aid in sedimentation.

Plant species in this zone includes both submergent and emergent vegetation. Submerged plant species should be planted in water depths between 0.30 m and 0.50 m. Emergent plant species should be planted in water depths between 0 and 0.30 m. The side slopes will determine the amount of vegetation that can be established.

## 5C.8.2 Fringe Areas

Where accumulated runoff in the wet pond is used for irrigation or other re-use purposes, special attention to the resulting soil moisture regime is needed to ensure the survival of the vegetation.

### 5C.8.2.1 Shoreline Fringe Areas

Shoreline fringe areas are the areas subject to frequent wetting from storm events. In general, this is the land delineated between the NWL and HWL for erosion/water quality control. This area will typically have higher soil moisture conditions during the frequent storm events. The area close to the NWL elevation is subject to more frequent flooding and wave action from the pond and must be adequately protected from erosion.

The planting strategy for this area should be similar to a shallow marsh area. Plant species should include hardy hydric grasses and shrubs. Due to the frequency of inundation, plant stocks should be used instead of seeds.

### 5C.8.2.2 Flood Fringe Areas

When the wet pond is used to control peak flow rates, a zone of infrequent inundation is created. This zone is referred to as the flood fringe area and is generally the area just below and slightly above the NWL. Plant species in this zone should include a range of grass, herb, and shrub species. In general, trees are to be planted above the HWL.

In addition, thorny or dense vegetation may be planted to provide safety measures, as an alternative to fencing. Together with other plantings, an effective barrier to public entry can be created.

## 5C.8.3 Upland Areas

Upland areas are the landscaped areas above the HWL that provide aesthetic amenities around the pond. Plant species should be designed to restrict access to steep areas or inlet/outlet locations. A naturalized landscape should be designed to consider:

- Topography and drainage;
- Soil conditions;
- Adjacent plant communities;
- Availability of nursery stocks;
- Potential for on-site transplantation; and
- Minimal maintenance.

Any pathways to be incorporated must be constructed above the 1:100 year elevation (HWL). Pathway locations and design should also have regard for protection of any native habitats created or protected.

## 5C.8.4 Pond Edge Treatment

Edge treatment or shore protection is required. The area close to the NWL elevation is subject to more frequent flooding and wave action from the pond. This area must be adequately protected from erosion. Treatment must be compatible with the adjacent land use and must provide for low maintenance and safety.

The edge treatment must cover the ground surfaces a horizontal distance of 1.50 m below and 3 m above NWL, measured horizontally. The treatment must be adequate to prevent erosion of the edge due to wave action. The area within 5.0 m of NWL measured horizontally should be left in a naturalized state following the establishment of vegetation.

Although a typical treatment is granular material on top of filter fabric, the designer is encouraged to propose alternate edge treatments that exceed this standard and provide an overall “softening” effect, such as turf reinforcement mats.

### 5C.8.5 Grading/Slopes

Grading and landscaping of the pond and adjacent areas are important for public safety and the functionality of the pond:

- Grading above the HWL must be no steeper than 4:1 to 5:1. Subject to the approval of the City, steeper side slopes in localized areas may be allowed above the HWL for a limited distance, provided that a 2.0 m wide safety bench is provided above the freeboard elevation;
- Grading between NWL and HWL must be no steeper than 5:1, with slopes less than 7:1 preferred;
- Below NWL, a 3:1 slope is required for a horizontal distance of 2.0 m. This is to discourage weed growth and public access; and
- The remainder of slope below NWL must be between 5:1 and 7:1.

## 5C.9 Geotechnical

A geotechnical investigation must be undertaken and a report prepared by a qualified geotechnical consultant that addresses issues related to the design of the wet pond. The purpose of the report is to determine criteria such as underdrainage design (e.g. toe drains), liner requirements (infiltration), and any other special design conditions such as slope stability or groundwater. Other considerations could include exfiltration (from pond to aquifer), construction dewatering, and possible liner uplift.

The pond bottom material is to be composed of impervious material with a suitable low permeability (permeability coefficient in the order of $1 \times 10^{-6}$ cm/s). Preference should be given to using clay, where possible, or an acceptable alternative; puncturing of liner materials during sediment removal is a concern. Organic soils are not permitted for use as a liner; however, they are permitted along the edge of benches for establishing vegetation.

The report must be submitted to, and approved by, the City prior to submission of the construction drawings. The geotechnical report should be submitted with the design report for the stormwater management facility. Required details must be indicated on the construction drawings.

## 5C.10 Inlets

Depending on the design of the wet pond, an inlet is generally the only type of structure that permits the inflow of stormwater into the pond. In order to provide water quality treatment, the flow must go through the wet pond to the opposite end. Inlet requirements include the following:

- Inlets should not be located close to the outlet control structure to minimize short-circuiting.
- Ideally there should only be one discharge location, or inlet, into the wet pond. Multiple inlets should be avoided where possible.
- All inlets and outlets are to be fully submerged, with the obvert of the pipe a minimum of 1.20 m below NWL. Partially submerged inlets are not permitted due to ice formation concerns.
- Inlet and outlet pipe inverts are to be a minimum of 100 mm above the pond bottom; depths in excess of 100 mm are recommended to prevent sedimentation from blocking the inlet pipe. Erosion control measures must be provided at the bottom of the inlet structure(s) to control erosion and scour.
- Erosion control measures should include the installation of a hard-bottomed surface, interlocking stone, or an approved concrete revetment/armouring system near the inlet pipe. Other enhancements, such as dissipaters or deflection structures, will help to minimize scour and re-suspension. The erosion protection must extend along the side slope to the bottom of the forebay to a distance where the velocity is no longer erosive.
- Inlet velocities (at the end of the incoming pipe) should be limited to 1.50 m/s where possible to minimize erosion and scour, as well as re-suspension of sediments.

- The invert elevation of the inlet pipe(s) to the first MH upstream from the wet pond must be at or above the NWL of the pond to avoid deposition of sediments in the inlet and freezing problems.

## 5C.11 Outlet Control Structures

Typically, an outlet control structure (also referred to as the "control structure" or the "outlet structure") serves as the source of control for the release of stormwater from the pond and the preservation of the NWL elevation. It is important that the structure be properly designed and constructed to provide minimal maintenance and enhance safety. Design of the outlet control structure must be approved by the City.

The outlet control structure for a wet pond preferably consists of three chambers, although some outlet control structure designs include only two chambers. In a three-chambered structure, there are usually two weir walls: one to control the NWL and one to control the HWL. For maintenance purposes, the size of each chamber should be a minimum of 1.20 m, but the preferred size is 1.80 m.

### 5C.11.1 Orifices

Usually an orifice provides control for the permitted release rate for the pond. The recommended minimum orifice diameter is 50 mm, to minimize the occurrences of clogging at the outlet. The preferred minimum diameter is 100 mm.

Subject to approval by the City, orifice configurations other than circular openings can be considered. However, circular configurations with a slot are preferred for orifices along the floor bottom, because they better promote swirling flow and scour of deposited sediment at the bottom of the orifice. Supporting information, including hydraulic calculations for the proposed configurations, are to be provided to the City as part of the pond report submission.

Where small orifices are required, consideration should be given to providing an overflow outlet that would operate in the event that the primary orifice becomes blocked.

The orifice plate should preferably be constructed of stainless steel (306); however, galvanized steel or an approved equivalent are acceptable. The minimum gauge must be 3 (6 mm).

### 5C.11.2 Weir Walls

Wet ponds will typically have two weir walls in the outlet control structure: one to control the NWL, and one to control the HWL to provide a source of overflow for the pond in the event that the orifice becomes blocked. The weir wall controlling the overflow should be set at the HWL elevation, or the calculated hydraulic grade line elevation.

### 5C.11.3 Bypass Gate Valves

All wet ponds require a bypass gate valve. The bypass gate valve is used as a bypass for the orifice in the event the orifice plugs, as well as for maintenance purposes. Although there is no set size specified, a minimum gate size of 300 mm diameter should be targeted where possible. The design flow in the downstream storm pipe should not be exceeded, except in emergency situations.

With the three-chamber design, two bypass gate valves are required, one in the NWL weir wall and one in the HWL weir wall.

All gates should have non-rising stems that are operated either mechanically or manually (with a T wrench). The T wrench should be located on the downstream end of the outlet control structure in an easily accessible location.

## 5C.12 Maintenance Vehicle Access

The following must be provided:

- The vehicle access route must be a minimum of 3.50 m wide, but preferably 4.0 m wide. Additional consideration for width at turns and bends is required, with a minimum turn radius of 12 m. The City may consider this being integrated into the trail network;
- Suitable material must be used in the road construction to provide a hard (e.g., pavement, gravel, etc.), durable all-weather surface;
- A boat ramp must be provided to the forebay, and the boat ramp must extend to at least 1.0 m below the NWL. This ramp must be constructed of concrete or some other surface that is demonstrated to be able to withstand saturation; and
- The entrance must be gated, with bollards or equivalent at the property line (or any location where a public vehicle could otherwise access the pond site), to prevent unauthorized access. See Section 8.1.3.1 for further details concerning the installation of bollards.

## 5C.13 Signage

The following must be provided:

- Signs indicating the location of all inlets and outlets, posted at the adjacent high water elevation, as shown in Standard Drawing 5-400; and
- Signs warning of the nature of the Stormwater Management Feature as shown in Standard Drawings 5-401, 5-402, 5-403, and 5-404 as applicable, posted at the high water elevation in locations selected by the City.