City of Saskatoon

Design and Development Standards Manual

Section Six

Storm Water Drainage System

Version 17

City of Saskatoon

City of Saskatoon

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1 Objective

Storm runoff generated within any development shall be routed through a conveyance, storage, and/or treatment system to regulate the rate of outflow and the quality of the water that is released into the South Saskatchewan River.

The storm drainage system shall be designed to consider safety, environmental protection, quality of life, and life cycle costs.

The storm drainage system shall be designed to be completely separate from the sanitary sewer collection system. Interconnectivity with sanitary sewer mains is not acceptable.

2 Submissions and Approvals

The Proponent is responsible for being aware of the regulatory requirements governing the development of the storm drainage system, and for compliance with these requirements.

Regulatory and supporting documents that shall be referenced for the design and installation of the storm drainage system include the following:

- *Sewer Use Bylaw (Bylaw No. 9466)*, City of Saskatoon;
- *Drainage Bylaw (Bylaw No. 9772)*, City of Saskatoon;
- *Residential Property Lot Grading Guidelines*, City of Saskatoon;
- *Private Crossings Bylaw (Bylaw No. 4785)*, City of Saskatoon;
- *Private Crossings over Ditches (Bylaw No. 9730)*, City of Saskatoon;
- *Curb, Sidewalk and Ditch Crossing Information Package*, City of Saskatoon;
- *Standard Construction Specifications and Drawings: Roadways, Water, and Sewer*, City of Saskatoon;
- *Park Development Guidelines and Standard Construction Specifications*, City of Saskatoon;
- *Landscape Guidelines*, City of Saskatoon;
- *Low Impact Development Design Guide for Saskatoon*, City of Saskatoon;
- *Stormwater Guidelines EPB 322*, Saskatchewan Environment;
- *Wetland Policy*, City of Saskatoon;
- *Wetland Design Guidelines*, City of Saskatoon;

- *The Environmental Management and Protection Act*, Province of Saskatchewan;
- *Waterworks and Sewage Works Regulations, E-10.22 Reg 3*, Province of Saskatchewan;
- *Water Security Agency Regulations, W-8.1 Reg 1*, Province of Saskatchewan;
- *Saskatchewan Employment Act, S-15.1*, Province of Saskatchewan;
- *Occupational Health and Safety Regulations, 1996, O-1.1 Reg 1*, Province of Saskatchewan;
- *The Plumbing Regulations Chapter, P-37.1 Reg 13*, Province of Saskatchewan;
- Private Sewage Works Regulations, P-37.1 Reg 14, Province of Saskatchewan;
- *The Fisheries Act*, Department of Fisheries and Oceans;
- *The Navigable Waters Protection Act*, Transport Canada;
- *The Canadian Environmental Protection Act*, Environment Canada;
- *Hydraulic Structures*, Smith, C.D., University of Saskatchewan, Printing Services;
- *The National Building Code*, Canadian Commission on Building and Fire Codes, National Research Council of Canada;
- *Canadian Environmental Quality Guidelines*, Canadian Council of Ministers of the Environment;
- *PVC Pipe: Design and Installation*, (M23), AWWA; and
- *PE Pipe: Design and Installation*, (M55), AWWA.

2.1 City of Saskatoon

The City of Saskatoon (CoS) requires the submission of a *Storm Water Drainage Plan* based on modelling of the proposed storm water drainage system and a *Storm Water Storage Basin Design Report.*

2.1.1 Storm Water Drainage Plan

At the neighbourhood concept stage, an analysis of the major and minor systems shall be carried out. The model shall be submitted to the CoS for verification. The conceptual *Storm Water Drainage Plan* shall contain the following elements:

- A general description and site plan of the proposed development.

- A description of, and figures showing, the pre-development hydrology of the site.
- A description of groundwater depths with reference to existing and proposed ground surface elevations, and groundwater mitigation plan as described in Section 2 of the Design and Development Standards Manual.
- A description of, and figures showing, the proposed post-development topography and hydrology.
- A description of, and figures showing, the proposed staging of development and the storm water drainage infrastructure to be constructed during each major stage.
  - This shall include identification of potential locations for oil/grit separators.
- A description of, and figures showing, the proposed storm water retention facilities to be constructed during each major stage of development.
- Identification of the impacts that the proposed development will have on the drainage of the local watershed.
- Justification for any proposed deviations from standard storm water management practices.
- A description of the erosion control methods that are to be used during construction and during the life of the storm water drainage system.
- A description of flow rates, boundary conditions, and any other assumptions used for modelling, together with calculations and/or the rationale for their use.
- A description of any simulation results. Actual model run data shall be appended to the *Storm Water Drainage Plan*.

For detailed design, modelling of the major and minor system shall be carried out for each stage of development. The staged *Storm Water Drainage Plans* shall include the same elements as the conceptual plan, but shall be specific to each stage of development. Models shall be submitted to the CoS for verification.

The CoS reserves the right to require resubmission of the *Storm Water Drainage Plan* if there are any changes to the proposed development that significantly affect the storm water drainage system and/or hydraulic analysis. Resubmissions shall be required at the discretion of the CoS and shall typically relate to changes in the configuration of the system and/or changes to proposed land uses.

At the lot level design stage, a storm water design brief report will be required for new, infill, and redevelopment sites. Storm water design reports shall include proposed land uses, storm water drainage plans and calculations, and on-site storm water management. Developers are encouraged to consider Low Impact Development (LID) as an option for on-site storm water management which may enable reduced equivalent runoff unit (ERU) charges of the site accordingly or Storm Water Management Credits. A design guide of various LIDs can be found on the City of Saskatoon website – "*Low Impact Development: Design Guide for Saskatoon.*" Refer to Table 1: Runoff Reduction for various BMP's in "*Low Impact Development: Design Guide for Saskatoon*" when considering LID for on-site storm water management. An application for Storm Water Management Credits should be made when submitting the storm water design reports for conditional approval.

2.1.2 Storm Water Storage Basin Design Report

Proponents shall submit the following information, at the neighbourhood concept stage, to the CoS for each proposed storm water storage basin (SWSB):

- A site plan showing the area served by the SWSB.
- Justification of the need for the SWSB.
- A description of each proposed basin, including drainage area, normal water level, and intended function.
- The results of the soil investigation for each SWSB.
- A design summary and present worth life cycle maintenance cost estimate for each SWSB.
- A comparison of technically viable options, if applicable. The technical and economic rationale for the preferred option shall be clearly outlined.
- Estimated inflows and outflows at the initial stage of construction, by phase, and at full buildout.
- Identification of opportunities for recreational activities.

The CoS shall be responsible for coordinating the design of each SWSB including:

- Design drawings and stage/storage/discharge rating curves.
- Modelling of basin performance under various operating conditions.
- Development of an erosion control program during construction and over the life of the SWSB.
- Development of a monitoring and maintenance program and costs to complement the intended function of the SWSB.
- Development of an operation and maintenance manual for each facility.
- Delineation of maintenance access road for vehicular access.

2.2 Other Authorities

The Proponent shall be responsible for obtaining approvals from the appropriate authorities in a timely manner.

3 Design Flows

The storm drainage system for proposed developments shall consist of both major and minor components.

The minor system consists of piping, manholes, catch basins, and outfall structures that are able to convey runoff from more frequent, lower intensity storm events to the receiving water.

The major system consists of overland street drainage, detention facilities, park land, ditches, swales, and any other land that is required to convey runoff from less frequent, higher intensity storms that produce runoff in excess of what the minor system typically handles.

3.1 Minor System

The minor system shall be designed to accommodate the 1-in-2 year design storm event.

- The Rational Method shall be used to determine design flows.
- Computer modelling shall be used to confirm design.

The minor system shall be evaluated to confirm that runoff during design events will be conveyed to adequate receiving waters without surcharging the pipe system.

The release rate from any proposed development shall not exceed the capacity of the downstream system, or as set by the CoS.

3.2 Major System

The major system shall be designed to accommodate the 1-in-100 year, design storm event. The initial active volume (m^3) of SWSBs can be estimated from 750×Area (ha).

The grading of streets and the layout of the major drainage system shall be assessed to ensure the maximum depth of ponding on the road to not exceed 0.35 m for all roadways. Continuity of the overland flow routes between adjacent developments shall be maintained. Computer modelling shall be used to confirm design.

3.3 Rational Method

The formula for the design peak runoff rate shall be:

$$Q = 2.78 \times C \times I \times A$$

Where Q = Design peak flow rate (L/s)

C = Runoff coefficient

I = Rainfall intensity that corresponds to the time of concentration (mm/hr)

A = Area of contributing runoff surface (ha)

3.3.1 Rainfall Intensity, Duration, and Frequency Data

Rainfall intensity, duration, and frequency (IDF) data, calculations, and curves for Saskatoon can be found in Table B-1 and Figure B-1 of Appendix B. The IDF curves have been updated to incorporate the climate chance impacts.

3.3.2 Time of Concentration

The duration of rainfall used to determine intensity is equal to the time of concentration. The time of concentration equals the time of overland flow to the storm drainage system inlet plus the time of travel in the upstream conduits.

- The overland flow time to curb side in residential and commercial areas shall not exceed 10 minutes in duration.
- Specific overland flow times shall be computed separately for industrial and undeveloped areas.
- Gutter flow time shall not exceed 5 minutes.
- The maximum time of concentration to an upstream inlet for a residential development shall be 15 minutes.
- The time of travel in the conduit shall be based on full flow velocity.

3.3.3 Coefficient of Runoff

The value of runoff coefficients shall be estimated from the following equation:

$$C = \frac{(C_nA_n) + (C_{n-1}A_{n-1}) + \ldots + (C_1A_1)}{A_n + A_{n-1} + \ldots + A_1}$$

Where C = Runoff coefficient, see Table B-2 in Appendix B

A = Area, gross

N = Denotes sub-areas, distinguished by land use

3.4 Modelling

A hydraulic analysis shall be required for every proposed development and for every change that significantly impacts a previous hydraulic analysis. The hydraulic model shall include both minor and major systems. The results of the modelling shall be summarized in the *Storm Water Drainage Plan* and submitted to the CoS for approval.

The selection of an appropriate computer model shall be based on an understanding of the principles, assumptions and limitations of the system being designed. The preferred software package is the current release of XPSWMM. Submissions for approval using alternate modeling software shall be pre-approved by the CoS.

- The CoS shall provide information for existing nodes that will be connection points for the proposed network.
- The CoS shall provide the datum for node elevations.
- Tables B-3, B-4, and Figure B-3 in Appendix B contains required calculations and information for the design storm hyetographs. Chicago method is current CoS acceptable hyetograph distribution.
- Table B-5 in Appendix B contains information for the XPSWMM model sub-catchments and soil parameters.
- All sub-catchment polygons and corresponding areas need to be shown and connected to their relevant nodes in the model background.

Modelling of the major and minor system shall include:

- Pre- and post-development hydrology with identification and quantification of all major points of drainage entry into and exit from the proposed development.
- Inclusion of the underground piping system, storage areas, hydraulic structures and controls, all streets, swales, linear parks and other major routes of overland flow.
- The proposed staging of development and implementation of storm water management practices for each major stage.
- Simulation of 1-in-2 year, 1 hour design storm for the minor system including all underground pipes, hydraulic control structures, storage areas, and outfalls.
- Simulation of 1-in-5 year, 1 hour design storm for the minor system, as mentioned above and major systems including all streets, swales, linear parks, and other major routes of overland flows.
- Simulation of the 1-in-100 year, 1-hour design storm for the minor system, as mentioned above, and major system including all streets, swales, linear parks and other major routes of overland flows.
- Simulation of the 1-in-100 year, 24-hour design storm for SWSBs with the drainage time exceeding 24 hours. Application of both 24-hour Chicago hyetograph distribution and June 24, 1983 historical event to determine and use the governed storm to size SWSBs.
- Simulation of the 1-in-100 year, 48-hour design storm for SWSBs with the drainage time exceeding 48 hours. The 48-hour design storm consists of two separate and consecutive storms each with a 24-hour Chicago hyetograph distribution, as shown in Figure B-3.

3.4.1 Water Levels

In systems with an SWSB, the effects of the high water level shall be considered in the design of the minor system and property drainage.

Depressed Linear Parks and Drainage Channels

- The HWL of the 1-in-100 year event shall be restricted to public lands in all cases.
- Adjacent basement openings shall be constructed above the HWL.
  - All basement windows openings shall be constructed with a freeboard of 0.15 m above the HWL.
  - Walkout basements shall be constructed with a freeboard of 1.0 m between **the** HWL and property line unless otherwise approved by the CoS.
  - CoS may approve freeboards less than 1.0 m for walkouts along the linear parks/drainage channels if the developer can provide appropriate justification.

Lot Elevations:

- All building entrances and windows shall be at least 0.15 m above the HWL of the 1-in-100 year event.

SWSB Design:

- A dry pond's outlet capacity shall be such that the facility shall drain and reach NWL within 24 hours of reaching HWL during the design event.
- A wet pond's outlet capacity shall be such that the facility shall drain and reach NWL within 48 hours of reaching HWL during the design event unless otherwise approved by the CoS. **I**f the CoS approves drainage time more than 48 hours, then 48-hour design storm shall be used to size the wet pond.
- The SWSBs shall be designed with a minimum of 1.0 m free board between pond HWL, calculated from the XPSWMM model, and property line.

3.5 Gravity Flow: Minor System

The piped system shall convey the design flow when flowing full with the Hydraulic Grade Line (HGL) at the pipe crown. The Manning Equation shall be used for the design and modelling of gravity flows in storm drainage pipes.

$Q = (A \times R^{2/3} \times S^{1/2})/n$

Where: Q = Flow (m^3/s)

A = Cross sectional area of pipe (m^2)

R = Hydraulic radius (area/wetted perimeter) (m)

S = Slope of hydraulic grade line (m/m)

n = Manning coefficient = 0.013 for all approved materials in straight alignment ($s/m^{1/3}$)

3.5.1 Velocity

Flow velocities shall not be less than 0.90 m/s at full flow.

- When the flow velocity exceeds 3.0 m/s, special consideration shall be given to invert erosion in the piping.

3.5.2 Size

The minimum size of storm drainage piping shall be 300 mm diameter.

3.5.3 Slope

Minimum slopes, based on full flow, which shall be permitted for various pipe sizes are provided in the table below.

- Maximum slopes shall be based upon limiting the maximum flow velocity.

Table 3-1a
Minimum Permitted Pipe Slope at Full Flow
For Straight Sewers

Pipe Size (mm)	Minimum Slope (%)
300	0.44
375	0.32
450	0.26
525	0.22
600	0.18

675	0.15
750	0.13
900 and larger	0.1

3.5.4 Curved Pipes

If storm drainage pipes are curved, the coefficient of roughness and minimum acceptable slopes shall be subject to the approval of the CoS.

Table 3-1b
Minimum Permitted Pipe Slope at Full Flow
For Curved Sewers

Pipe Size (mm)	Minimum Slope (%)
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

3.6 Gravity Flow: Major System

On overland flow paths of non-drainage parcels including streets, the combination of velocity and depth of overland flow shall not exceed the values outlined in the following table:

Table 3-2
Permissible Depths for Submerged Objects

Water Velocity (m/s)	Permissible Depth (m)
0.5	0.80
1.0	0.32
2.0	0.21

3.0	0.09

Source: *Stormwater Management Guidelines*, Alberta Environment, 1999.

In areas where the permissible depth and velocity values specified in Table 3-2 are difficult to satisfy, such as in close proximity of culverts in linear parks, appropriate safety measures shall be included in the design for consideration of approval by the CoS.

4 Property Drainage

Storm drainage water from residential developments (one-unit dwellings or two-unit dwellings) is allowed to be drained onto the public right of ways. All other parcels shall drain internally towards designated areas before they drain or spill over to the City of Saskatoon minor and major storm water drainage system. Proponents shall develop storm water management plans to be submitted to CoS for review and approval. Under no condition shall a private property direct its drainage to another property unless it is a designated drainage route.
Standard drawings that should be referenced for site and lot drainage are listed in Appendix A.

4.1 General Drainage

An allowable range of 2% to 4% slope shall be used for general property drainage.

4.1.1 Lot Grading

The lot grading plan shall be developed to make sure properties adjacent to the major storm conveyance system are above the 1 in 100 year design storm water level. Groundwater levels shall also be considered in grading plan to ensure basement foundation footings are above the groundwater level as outlined in Section 2 of the Design and Development Standards Manual.

The proponent shall consider lot grading plans rear property line design elevations and slopes to ensure minimal mid-block lot drainage style transitions.

The proponent shall provide garage pad design elevations indicated on the lot grading plan to ensure adjacent attached garages are constructed at the same elevation.

4.2 Drainage Easements

Where storm water drainage for a grouping of lots is directed along one or more property lines, the Proponent shall provide a drainage easement.

4.2.1 Slope

The minimum slope for drainage channels at common residential property lines is:

- 1.0% for grassed channels.
  - ➢ This may be reduced to zero if all lots along the common property line drain from back to front.
- 0.5% for concrete-lined channels.

The minimum slope for drainage channels at common commercial or institutional property lines is 0.5% for grassed or concrete-lined channels.

- If a commercial or institutional property line is common with a residential property line, then the minimum slopes for the residential property shall govern.

Where back lot drainage is common to flankage and more than 1,000 m^2 is drained along a side yard:

- The side yard shall be configured with a catch basin in the back.
- A concrete channel with a minimum slope of 0.5% shall be placed along the side yard.

4.2.2 Length and Configuration

- The length of a channel from high point to discharge point shall not exceed 200 m.

- Bends between the high point and the discharge point shall not exceed 40°.

4.2.3 Discharge Points

Discharge points shall be at the intersection of the drainage easement with a street, walkway, concrete swale, or catch basin.

- When a walkway or concrete swale is used as a discharge point:
  - The minimum slope of the walkway or concrete swale shall be 0.5%.
  - The length of the sidewalk shall be included as part of the total easement length.
- When a catch basin is used as a discharge point, a concrete pad shall surround the basin and extend at least 1.0 m from the edge of the basin.

4.3 Approaches and Culverts

Culverts are utilized under approaches to maintain ditch drainage in some areas of the City. All approaches that cross public right-of-ways, including boulevards or drainage ditches, require a Private Driveway Crossing Permit from Transportation (excluding lots with ditch and culvert drainage within the Montgomery Place neighbourhood). Residents with ditch and culvert drainage in Montgomery Place require a Private Ditch Crossing Permit through Saskatoon Water. Minimum standards for the design of approaches and culverts are specified in Standard Ditch Crossing Requirements, which is part of The Curb, Sidewalk and Ditch Crossing Information Package. A separate Ditch Crossing Information Package is available for the residents of Montgomery Place with overland drainage. Culvert use shall be pre-approved, and design shall be carried out and inspected under the direction of the CoS.

New surface infrastructure installations such as power poles, utility boxes, transformer boxes, curb stops, hydrants, etc. shall be installed at least 1.5 m away from culvert ends (downstream and upstream). These new infrastructure installations shall be offset at least 1.0 m from the ditch centerline flow path. The installations shall also not alter the ditch cross-section.

4.4 Maximum Allowable Discharge Rate and Onsite Storage Requirement

Multi-family residential, commercial and industrial land uses may propose runoff coefficients higher than the design values. Also many old areas of the City were designed with runoff coefficients lower than the values listed in Table B-2. In these instances, the flow rate to the city storm management system shall be restricted using flow restriction devices to flow rates as per the minor system design flows. The following equation can be used to calculate the allowable release rate into the city system in a 1-in-2 year storm.

Flow (L/s/ha) = $114 \times C_d$

where C_d is the design runoff coefficient of the site for 1-in-2 year storm, as per the area concept plan or original design. To determine the design runoff coefficient in developed areas, contact CoS prior to designing and applying for a building permit.

Onsite storage is also mandatory for the parcels having runoff coefficients higher than the design values. The following equation can be used to estimate the required onsite storage volume:

$$\text{Volume } (m^3/ha) = C_a \times (C_p - C_d) + C_b \times (C_p - C_d)^2$$
$$C_a = 869 - (200 \times C_d),\ C_b = 33 - (1055 \times C_d)$$

Where C_p is the proposed runoff coefficient for 1-in-2 year storm.

Onsite storm water management is also required on re-development sites. When constructing a new building or parking lot or adding to an existing building on a paved re-development lot is proposed, storm water management requirements will apply only to the incremental development.

Example 1: New Development Site
A 2.0 ha commercial site has been allocated C_d=0.60 as per the original system design. The developer has proposed a higher runoff coefficient, C_p=0.85 for the site. The allowable release rate to the minor system and onsite storage are calculated as:

Allowable release flow:
Unit flow rate = 114×0.60 = 68 L/s/ha,
Total flow rate = 68 ×2 = 136 L/s

Onsite storage requirement:
C_a = 869-(200×0.60) = 749, C_b = 33-(1055×0.60) = -600
Unit volume = 749×(0.85-0.60)-600×(0.85-0.60)^2 = 150 m^3/ha
Total Volume = 2×150 = 300 m^3

Example 2: Incremental Development Site
A 2.0 ha commercial site has been allocated C_d=0.30 as per the original system design. The developer wants to add a new building and/or parking lot of 600 m^2 size with a proposed runoff coefficient, C_p=0.95 for this incremental development. The allowable release rate to the minor system and onsite storage are calculated as:

Allowable release flow:
Unit flow rate = 114×0.30 = 34.2 L/s/ha,
Total flow rate = 34.2 ×0.06 = 2.05 L/s

Onsite storage requirement:
C_a = 869-(200×0.30) = 809, C_b = 33-(1055×0.30) = -283.5
Unit volume = 809×(0.95-0.30)-283.5×(0.95-0.30)^2 = 406.07 m^3/ha
Total Volume = 0.06×406.07 = 24.40 m^3

5 Design of Minor System Components

Standards for the design of catch basins, pipes, manholes, and outfalls are presented in this section. Standard drawings that should be referenced for the design of minor system components are listed in Appendix A. Placement of catch basins and maintenance covers should not be located within the accessible route, including sidewalks, accessibility ramps, refuge areas, and other pedestrian pathways in accordance with requirements stated in Section 8 – Transportation of this manual. If utilities must be located within a cycling facility, appropriate grade type and direction must be installed.

5.1 Catch Basins

Catch basins shall be installed to intercept all overland flows, including flows in back lanes and gutters/swales.

5.1.1 Drainage Length

- The first catch basin (furthest upstream) in any portion of the storm drainage system shall be located a maximum distance of 200 m from the nearest high point.
- Catch basins within the storm drainage system shall have a typical maximum spacing of 120 m.

5.1.2 Capacity

- Surface water shall be intercepted with a number of catch basins such that the inlet capacity is sufficient to receive the design storm water flow.
- Catch basin capacity shall be considered for both sump conditions and on inlet grate type.

5.1.3 Barrels

All catch basin barrels shall be 600 mm or 900 mm precast, sulphate resistant concrete sections. A sump shall be provided.

5.1.4 Leads

All catch basin leads shall discharge directly into the storm drainage system at a manhole.

- The maximum lead length shall be 30 m.
- The minimum lead size shall be 250 mm with a minimum slope of 2%.
- A 300 mm diameter lead may be used with a minimum slope of 1%.

Two catch basins may be connected to one lead. In this case:

- The minimum lead size shall be 300 mm.
- The minimum slope shall be 2%.

5.2 Pipes

The storm sewer collection system shall consist of two types of pipes, as outlined in the following table:

Table 5-1
Pipe Description

Type	Storm Water Path	Diameter (mm)
Local Storm Pipe	From service connections and catch basin manholes to trunk	Minimum 300
Trunk Storm Pipe	From neighbourhoods to receiving water	Minimum 1350

Pipes connecting neighbourhood ponds into storm trunks are also considered trunks although their size may be less than 1350 mm. The minimum recommended size for pond connections is 900 mm. No direct servicing is allowed by storm trunks unless approved by CoS.

5.2.1 Sizing

Storm water pipes shall be sized to accommodate the design flows for the proposed contributing area and if applicable, to reasonably accommodate extensions to adjacent future development areas as described in the sector plan for each development area.

5.2.2 Depth of Cover

The depth of the minor storm water drainage system shall be sufficient to meet the following requirements:

- Frontage piping shall be of adequate depth to receive connections from adjacent properties.
- Minimum depth of cover of 1.85 m to the crown of the pipe.
- In green spaces this depth may be reduced through the use of catch basin manholes, only as approved by the CoS.

5.2.3 Clearance

- The minimum vertical clearance from the bottom of one pipe to the top of the next lowest pipe shall be 150 mm.
- Where pipes are laid on undisturbed soil, the minimum horizontal clearance between the outer walls of the adjacent pipes shall be 300 mm.
- If pipes are installed in a common trench with other pipes, clearances must be approved by the CoS.

5.2.4 Pipe Strength

The strength of the pipe shall be calculated on the basis of transition width trench conditions.

- Pipe strength and wall thickness shall be determined in accordance with AWWA standard design manuals for various pipe materials.
- Pipe bedding shall be determined as per the City of Saskatoon *Standard Construction Specifications and Drawings*.
- Minimum backfill weight shall be 2162 kg/m^3 unless a detailed geotechnical investigation indicates that a lesser value can be used.

5.2.5 Curved Storm Drainage Pipes

Curved storm drainage pipes may be built with radius pipe or bends.

- The minimum radius of curvature allowed shall be in accordance with manufacturer's specifications for the material.
- Curbs shall not be undercut to accommodate the curvature.

5.3 Manholes

Manholes shall be located at the upstream end of each line, at changes in size or alignment, at all junctions, and at all catch basin connections.

5.3.1 Locked Manholes

Manholes shall be locked when:

- Not located on a roadway.
- Located in crosswalks or along a public pathway.
- Located in proximity to an area that will be generally accessible to the public.

5.3.2 Spacing

The maximum spacing between manholes shall be 120 m for maintenance considerations.

- Greater spacing may be considered for pipes larger than 750 mm in diameter at the discretion of the CoS. In no case shall spacing be greater than 250 m.

- Maximum spacing for curved pipes shall be 100 m unless otherwise approved by the CoS.

5.3.3 Diameter

The minimum manhole diameter shall be 1.2 m.

- For pipes at depths greater than 6.0 m, special manholes with safety platforms at intermediate levels may be used at the discretion of the City's engineer.
  - The lowest platform should typically be above the incoming flow.
  - The maximum spacing of safety platforms is 6.0 m.

5.3.4 Hydraulic Losses

- Allowance shall be made for hydraulic losses through manholes by:
  - Maintaining grades of sewers and matching crowns for straight run manhole types.
  - Dropping the invert by 0.03 m at deflections of 45° to 90°.
  - Providing benching.

5.4 Oil and Grit Separators

Oil and grit separators (OGS) are underground detention structures that are designed to capture hydrocarbons and sediments on the principles of gravity-based sedimentation and phase separation for oil. They take the place of a conventional manhole in the storm water drainage system and are typically used in areas that are highly impervious with potential for discharge of hydrocarbons and/or polluted sediments. Installation of oil and grit separators results in extension of operational life of storm water management facilities and protection of environment from sediment and oil contamination.

Oil and grit separators are typically installed for small sites (< 2 ha) where a pond/wetland is not feasible for quality control. For larger sites (> 2 ha) oil and grit separators are usually allowed in a treatment train approach in conjunction with other approved storm water management options.

The minimum flow captured by an oil and grit separator shall not be less than the 1 hour 2-year post development flow. A design brief storm water management report shall be submitted to the City of Saskatoon along with site approval application. Approved oil and grit separators shall be installed as per the following criteria:

1. At interface of CoS storm water management system and industrial, commercial, institutional, and multi-residential sites with 1500 m^2 or greater paved area.

2. At interface of CoS storm water management system and gas stations, lube and oil change facilities, vehicle maintenance and mechanical shops, and sites with on-site fuel storage.

5.4.1 General Design Considerations

The particle size distribution (PSD) has a profound effect on total suspended solids (TSS) removal efficiency. The OGS units shall be sized to remove clay and silt particles from runoff to ensure that the majority of pollutants (hydrocarbons, nutrients, and heavy metals) that adhere to fine particles will be removed on-site and will not be discharged to the City's storm water management system.

To confirm treatment performance, OGS units need to be verified by the Canadian Environmental Technology Verification (CETV). CoS will accept a minimum of 80% annual TSS removal for particles size distribution used by CETV certification.

The proponent shall provide all calculations or modelling information showing required removal rates and sediments storage capacity provided for one year without washing the treated sediments.

Sizing calculations shall use the following guidelines:

- Total suspended solids (TSS) removal efficiency equivalent to enhanced level of treatment (80% TSS removal). For example, in order to get 80% TSS removal, a separator could be sized to capture 94% of the 2-year storm runoff volume with 85% removal efficiency.
- A bypass shall be provided for high storm water flow conditions to avoid re-suspension of settled solids.
- Calculations shall be based on City of Saskatoon IDF data with time of concentration of 15 minutes.

5.4.2 Maintenance and Repairs

The owner shall be responsible for maintenance and repairs of oil and grit separators installed on their property as per supplier's recommendations. Operation and maintenance requirements shall be noted in the design brief storm water management report for site development based on storage capacity of the units and shall be implemented by the owner to ensure that the required performance is achieved as per City's approval. Separators shall be maintained appropriately to reduce the sediment/hydrocarbon load entering the CoS storm water drainage system. Monitoring shall be required during the maintenance period and throughout the operating life of the separator.

5.5 Outfalls

The purpose of an outfall structure is to reduce flow velocity and prevent erosion.

- Outfall structures shall be placed at the end of all non-submersed storm drainage pipes that discharge to an open channel, watercourse, river, or other receiving water body.
- The structure shall be a chute, spillway, stilling basin, plunge pool with headwall, or other appropriate structure.
- The structure shall be designed in accordance with C.D. Smith's *Hydraulic Structures.* Other hydraulic design manuals may also be accepted at the discretion of the CoS.

5.5.1 General Design Considerations

- Outfall design should be reviewed for safety.
- Outfalls to a receiving stream or open channel shall be a minimum of 1.0 m above the NWL.
- Outfalls shall be located to avoid damage from moving ice during break up.
- Design shall prevent collection of debris on the apron.
- A cut-off wall is required at the end of the outfall apron to prevent undermining of the structure.
- Riprap and a filter layer, complete with geotextile, shall be placed downstream of the outfall structure where required to prevent erosion.
- Weeping tile shall be placed under the structure to reduce any water pressure behind the head wall.

- Grills shall be placed over all storm drainage outlets to prevent access.
- Railings shall be placed along the head wall and wing walls of the outfall structure.

6 Design of Major System Components

Standards for the design of grassed swales, wet ponds, dry ponds, and constructed wetlands are presented in this section. Standard drawings that should be referenced for the design of the storm drainage system are listed in Appendix A.

6.1 Grassed Swales

Swales can be natural or manmade and can be constructed only for conveyance or to temporarily store water and remove materials by infiltration and/or settling. Flow is typically conveyed toward a catch basin. The use of grassed swales must be approved and design shall be carried out under the direction of the CoS.

6.2 Storm Water Storage Basins: General

For the purposes of these standards, storm water storage basins (SWSBs) shall include wet ponds, dry ponds, and constructed wetlands. The use of a SWSB shall require the submission of a *Storm Water Storage Basin Design Report* and the approval of the CoS.

- In assessing the need for SWSB, the Proponent shall consider the impacts of uncontrolled drainage as well as the capital and operating costs of providing control.
- Where a SWSB is to have multiple functions, its design shall consider the safety and aesthetic implications of shape, grading and landscape features.
- Where possible, design shall incorporate measures for water quality improvement.
- The storm water retention area, up to and including the HWL, shall become public property.
- The storm water retention area above the 1-in-5 year storm elevation may be part of the required municipal reserve.
- Where possible, an emergency overflow system shall drain to a receiving stream for storms greater than the design event.
- Monitoring shall be required during the maintenance period to ensure that the storage basin is operating in accordance with its intended design flow, storage volume, and water quality improvement objectives (if applicable).
- The Proponent shall remove sediment from SWSBs and ensure that vegetation is adequately established by the end of the maintenance period.

- SWSBs located within four km of the Saskatoon Airport may be subject to Airport Zoning Regulations (AZRs). The AZRs may require special design features not covered in these standards.
- SWSBs shall have approved signage including safety precautions and other general public information.

6.2.1 Soil Investigations

Hydrologic and geotechnical investigations specific to the SWSB shall be undertaken to determine appropriate design factors.

- Constructed storage basins shall not act as either a recharge or a discharge area for groundwater.
- Where the basin is sited above a shallow aquifer the potential for groundwater contamination shall be minimized.
- Wet pond detention facilities shall be constructed in impervious soils to minimize water losses during dry weather periods.
- Intruding silt or sand seams shall be sealed off.

6.3 Wet Ponds

- Wet ponds are designed to retain and treat storm water runoff. They are typically located at local low points or adjacent to or part of an existing watercourse. Public access and safety issues are to be addressed in the design of the basin. Whenever possible, a constructed wetland should be located immediately upstream of the wet pond. Wet ponds shall not be constructed near a school without an approved barrier such as development, roadway, or fence between the SWSB and the school.

6.3.1 Configuration

- The preferred length: width ratio shall be from 4:1 to 5:1.
- The bottom of the pond shall be graded so that the facility can be completely pumped dry.
- Side slopes shall be no steeper than 3:1 from the bottom of the pond to 0.5 m below the NWL.
  - ➢ From 0.5m below the NWL to 3.5 horizontal meters above NWL, the maximum side slope shall be 7:1.
  - ➢ From 3.5 horizontal meters above NWL to the freeboard level, the side slopes shall be no steeper than 5:1.

- At NWL, the minimum depth shall be 2.5 m and the maximum depth shall be 3.0 m.
- Maximum active storage depth shall be 1.8 m.

6.3.2 Inlets and Outlets

Inlets and outlets shall be located to maximize detention time and circulation within the wet pond.

- Narrow and/or dead bay areas where floating debris may accumulate shall be avoided.
- Inlets shall be, where possible, a minimum of 1.0 m below the NWL. Otherwise, inverts of inlet pipes shall be above the water ice level.
  - ➢ Provision shall be made for sediment accumulation at points of inflow and for the periodic removal of sediment by maintenance crews.
- Outlet pipe crowns shall be at least 1.0 m below NWL, below ice level, and above the level of anticipated sediment accumulation.
  - ➢ Outlets shall operate by gravity.
  - ➢ Drainage control shall be located in the outlet control structure.

6.3.3 Edge Treatment

- Naturalized shorelines are preferred over inorganic shorelines. Inorganic shoreline treatments shall be provided for 1.5 horizontal meters below and 3.0 horizontal meters above the NWL. Inorganic shorelines shall make up no more than 30% of the total shoreline.
- Edge treatments shall be compatible with adjacent land use and consider safety, maintenance and access.
- The area around the wet pond, up to the design event flood level, shall be sodded or grassed, or protected with a silt fence, during the construction phase to prevent erosion and sedimentation.

6.4 Dry Ponds

Dry ponds are designed to act as a temporary holding facility for storm water runoff and to delay the release of runoff into the storm drainage system. Dry ponds are not considered to be a treatment facility for water quality improvement, although some removal of settleable solids may occur. Public access and safety issues are of concern, especially when the pond is in operation, and shall be addressed in the design of the basin. Dry ponds shall not be used to hold runoff from storms with a frequency of 1-in-2 years or less.

6.4.1 Configuration

The dry pond shall have dimensions that are acceptable to CoS.

- The preferred length: width ratio shall be from 4:1 to 5:1.
- Side slopes shall be no steeper than 5:1.
- The bottom of the pond shall be graded with minimum longitudinal and lateral slopes of 100:1.
- The bottom and sides shall be sodded or grassed.
- Maximum depth shall be 2.0 m at full operating level.

6.4.2 Inlets and Outlets

- A low flow bypass is required for flows from minor events.
- Grills shall be placed over all inlets and outlets to prevent access.

6.5 Constructed Wetlands

Constructed wetlands are preferred over wet ponds. Constructed wetlands consist of a forebay and a shallow environment suitable for the growth of aquatic and semi-aquatic plants. They may be used to provide an enhanced level of water treatment via sedimentation, filtration, and biological uptake. Constructed wetlands may be built in conjunction with downstream wet ponds and/or wetlands.

A basic set of guidelines to aid developers and designers in understanding design requirements for constructed wetlands can be accessed on the City of Saskatoon website: "*Wetland Design Guidelines*".

6.5.1 Overall Configuration

- Where possible, a wetland should be limited to 1 inlet and 1 outlet.
- Minimum side slope is 7:1.
- Active storage fluctuation depth should be limited to 1.8 m.
- Minimum 1.0 m of freeboard is required.

6.5.2 Inlet Pipe Configuration

- Inlets should be located with the longest flow path possible between inlet and outlet to minimize short circuiting.
- Submerged inlets are preferable, where the crown of the inlet pipe requires a minimum of 0.8 m below NWL, and the invert a minimum of 100 mm from the wetland floor.
- Unsubmerged inlets can be used provided the pipe invert is set at the HWL, and the inlet has a grating.
- If pre-treatment of flow through a forebay vortex separator is not possible, a skimming type manhole on the first manhole upstream of the inlet is recommended to prevent floatables from entering the wetlands.
- Inlet velocities should be limited to 1.5m/s where possible to minimize erosion or scour.
- Erosion control measures must be provided at the bottom of the inlet structure to control erosion and scour.

6.5.3 Sediment Forebay

- Sediment forebays should be designed to settle 0.150 mm sediment size with a settling velocity of 0.0003m/s, in a 1-in-2 year storm event.
- Forebay area is typically between 10-20% of the volume of the permanent pool or at least 10% of the wetland volume.
- Forebays are typically separated from the wetland by gabions, riprapped berm, or by an earthen berm with a controlled overflow with erosion protection. The height of the gabions or berm can be from NWL to 0.3 m above NWL.
- Minimum length to width ratio of the forebay is 2:1.
  - Flow baffles or other means of lengthening the flow path could be considered if minimum length to width ratio cannot be maintained.
- Forebay depth range is from 1-3 m.
- Minimum side slope below NWL is 5:1.

6.5.4 Permanent Pool Configuration

- Minimum side slope below NWL is 5:1.
- Permanent pool depths typically range from 150 mm – 300 mm.

- Deep zones with a minimum depth of 1 m should be introduced to redistribute flow across the wetland to encourage sheet flow.
- Any interior berms used for flow attenuation will have a minimum side slope of 5:1 below NWL, and 3.5:1 above. Width of the top of the berm will be a minimum of 1 m for foot traffic, and 3 m for vehicle traffic.

6.5.5 Wetland Outlet Configuration

- There are two main outlet flow structure configurations: reverse sloped outlet pipe and a perforated riser outlet pipe.
- It is preferable that all outlet pipes be fully submerged with the crown of the pipe a minimum of 0.8 m below discharging wetland NWL, and a minimum of 100 mm above wetland floor.
- Outlet control structures should be designed so that water level depth can be controlled in the wetland, including complete draining of the wetland.

6.5.6 Vegetation Establishment

- After excavation, grading, and 75 mm to 150 mm of topsoil placement, if manually planting emergent vegetation such as bare root, plugs, or potted material, the wetland should be kept flooded (saturated) until planting. At least 48 hours prior to planting, the wetland should be drained. After planting the soil must be kept saturated with minimal standing water of 100-200 mm until the plants are well established and have a growth to more than 0.5 m height. The wetlands can then return to normal functionality.
- Maximum drain time after a rain event should be kept to 48 hours to protect the viability of young plants.
- Experience suggests that from the time of germination to the time when the wetland can be brought up to the NWL is about 6-8 weeks.
- Maintaining saturated conditions can be done by pumping water into the wetland if dry conditions are present. This is particularly important if using wetland soils containing viable rhizomes/roots. If the wetland is being constructed with non-wetland soils, the wetland can remain dry until about one week before planting.
- When establishing or restoring vegetation, inspection every 2 weeks of vegetation health, density, and diversity should be performed.

- If the earthworks can be completed in the summer/fall period, the wetland can be seeded in the fall.
- If the wetland bottom elevation will not change and the existing soils are tight enough that the hydraulic conductivity is similar to that of clay compacted to 95-98% proctor, consideration can be given to retaining the wetland soil undisturbed in the areas that are at the correct bottom elevation.
- Seeds and plants supplied must come from the same climatic zone as Saskatoon and preferably from within 100 km radius.

7 Water Quality

Water quality objectives have been established for Saskatchewan and are outlined in the Saskatchewan Environment Surface Water Quality Objectives. These objectives are guidelines used to issue permits and to support/maintain designated water uses.

7.1 Sediment and Erosion Control

Sediment and erosion controls shall be provided at each level of development to minimize sediment discharge to the storm drainage system.

- This shall include properly graded and surfaced streets and lanes, landscaping, sediment control structures at pond and lake inlets, and other means where appropriate.
- Appropriate measures shall be incorporated in all developments to prevent any increase in the amount of downstream sedimentation or erosion. The following shall be considered to limit erosion and sedimentation impacts:
  - If a development causes downstream erosion and sedimentation despite the use of on-site controls, appropriate measures shall be constructed in the downstream areas.
  - Existing roadways and sidewalks shall be cleaned of sediments resulting from construction activities.
  - Sediment controls shall be placed at the location of downstream catch basins to prevent sediment discharge into the CoS storm water management system.

- Preservation of watercourse aesthetics and wildlife habitat shall be considered in erosion and bank stability work.

7.2 Monitoring Requirements

Proponents shall be required to monitor the water level, flow, storage volume, and water quality (if applicable) impacts of SWSBs and oil/grit separators during the maintenance period to demonstrate that the infrastructure is operating in accordance with the intended design.

- Specific monitoring requirements for individual facilities shall be determined by the CoS.
- A summary of monitoring results shall be submitted at the end of each year during the maintenance period.

7.2.1 Wet Ponds and Constructed Wetlands

During the maintenance period:

- Routine monitoring shall occur on a monthly basis to create a baseline database.
  - This will include pond-based sampling when there is no inflow.
- Annual monitoring shall take place during spring melt and immediately following three or more storm events.
- Monitoring shall typically include, but not be limited to, the following parameters:
  - Turbidity
  - Total Suspended Solids
  - Nitrogen
  - Total Phosphorous
- Additional monitoring requirements shall be based on proposed land uses in the surrounding watershed, as determined by the CoS.
- Monitoring records shall include the following:
  - A description of the weather conditions prior to and during monitoring, including precipitation amounts
  - Velocity and water level measurements

After the maintenance period:

- Annual monitoring shall take place in accordance with the monitoring and maintenance program developed by the CoS.

7.2.2 Dry Ponds

Samples shall be taken at both the inlet and the outlet of dry ponds during each monitoring event.

<u>During the maintenance period</u>:

- Monitoring shall occur immediately following three or more storm events and shall continue at a minimum of once daily until the facility has emptied, or as directed by the CoS.

- Monitoring records shall include the following:
    - ➢ A description of the weather conditions prior to and during monitoring, including precipitation amounts
    - ➢ Velocity and water level measurements

<u>After the maintenance period</u>:

- Annual monitoring shall take place in accordance with the monitoring and maintenance program developed by the CoS.

7.2.3 Oil and Grit Separators

Oil and grit separators shall be monitored at least once every six months during and after the maintenance period.

- Potential upstream erosion and/or hydrocarbon loading issues shall be reported immediately to the CoS.

8 Future Developments

In the event that storm water pipe stubs are provided for future developments, they shall be installed as deep as possible to maximize flexibility when the pipes are extended.

- Stubs shall be capped.
- Storm system stubs shall be staggered, by a minimum of 2.5 m, in relation to any other stubs to facilitate access in the future.

Appendix A Applicable Standard Drawings

Proponents shall be responsible for referencing standard drawings that are applicable to their development. Drawings are available from the City website.

Drawings are subject to revision, addition, or deletion. Revised drawings shall be renamed using the date of latest revision. Proponents are responsible for ensuring that they are referencing the latest version of any standard drawing.

Drawings that are applicable to the Storm Water Drainage System include the following:

Drawing Number	Title
Lot Drainage	
102-0022-003	Easement Grading Back Yard
102-0022-004	Easement Grading Side Yard Grading
102-0022-005	Drainage Swale Back of Lot, 1 of 2
102-0022-006	Grade Markers Electrical Kiosk
102-0022-007	Drainage Swale Back of Lot, 2 of 2
102-0022-008	Grade Markers Electrical Kiosk
102-0022-009	C.O.S. Lot Grade Markers Construction and Placement
102-0022-010	Drainage Improvement
102-0022-012	Side Yard Drainage Swale
102-0022-013	Lot Grading Transition Lot Type A/D & D/A
102-0022-014	Lot Grading Transition Lot Type D/C & C/D
102-0022-015	Lot Grading Transition Lot Type D/E & E/D
102-0022-016	Lot Grading Type A
102-0022-017	Lot Grading Type D
102-0022-018	Lot Grading Type C
102-0022-019	Lot Grading Type E
102-0022-021	Lot Grading Transition Lot Type C/E & E/C
102-0022-022	Side Yard Typical Concrete Drainage Swale
102-0022-023	Back Yard Typical Concrete Drainage Swale
Curbs and Walks	
102-0002-069	Concrete Swale
Storm Drainage System	
102-0018-001	Grating for Concrete Endwall Pipe Dia. Up to 1200 mm
102-0018-002	Grating for Concrete Endwall Pipe Dia. 1350 mm to 1800 mm
102-0018-003	Standard Handrail

Drawing Number	Title
102-0018-004	Standard Riprap Detail
102-0018-005	Storm Sewer Outfall
102-0018-006	Storm Sewer Outfall Reinforcement Details
102-0018-007	Handrail Details
102-0018-009	Standard Ditch Crossing Culvert Requirements
102-0018-010	Stormwater Storage Basin Cross Sections
Manholes	
102-0011-001	Manhole Safety Platform
102-0011-004	Standard 1050 mm Manhole for 200 mm to 525 mm Sewers- For Rehabilitation Work Only
102-0011-005	Standard 1200 mm Manhole for 200 mm to 600 mm Sewers
102-0011-006	Standard 1200 mm Manhole for 675 mm to 900 mm Sewers
102-0011-008	Drop Structure Manhole for Connection to Trunk Storm Sewers
102-0011-009	Standard 1200mm Manhole for 200 mm to 600 mm Sewers
102-0011-010	Circular PVC Pipe Beddings
102-0011-011	Circular Concrete Pipe Beddings
102-0011-012	Concrete Manhole Collars
102-0011-013	Lifter Ring Details
102-0011-014	Rubber Manhole Adjustment Riser
102-0011-016	Manhole Rehabilitation Where Thickness of Concrete Below Invert Exceeds 125 mm
102-0011-017	Manhole Rehabilitation Where Thickness of Concrete Below Invert Does Not Exceed 125 mm
102-0011-018	Sewer Force Main Inspection Manhole
102-0011-019	Standard Lockable CoS Manhole Frame & Cover for Public Properties
102-0011-020	Lock Wing & Spacers for Standard CoS Manhole Covers
102-0011-021	Standard Lockable CoS Manhole Frame & Cover for Private Properties
102-0011-022	TF-48 Beehive Grate
102-0011-023	TF-48 Beehive Frame
102-0011-025	TF-101 Beehive Frame
102-0011-026	TF-101 Beehive Grate
102-0011-028	Standard Manhole Types for Large Sewers – Notes and Schedules
102-0011-029	Standard Manhole Types for Large Sewers – Sections and Details
102-0011-030	Standard Manhole Types for Large Sewers – Cast-In-Place Details
102-0011-031	Standard Storm Sewer Subdrain Detail – Crown Depth up to 2.3m

Drawing Number	Title
102-0011-032	Standard Storm Sewer Subdrain Detail – Crown Deeper than 2.3m
102-0011-034	Standard Low Profile Manhole Frame for Rehabilitation Work Only
Catch Basins	
102-0010-002	Storm Drainage Catch Basin for Tandem Installation
102-0010-003	500 mm Round Catch Basin Frame and Cover
102-0010-004	Catch Basin Frame and Cover Surface Inlet Model
102-0010-005	Catch Basin Frame and Cover Curb Inlet Model
102-0010-006	Rolled Curb Catch Basin
102-0010-007	Precast Reinforced Round Catch Basin
102-0010-009	Installation of Catch Basin Lead for Sidewalk Const
102-0010-010	Hamilton Kent Pipe to Manhole Connector Specification Sheet
102-0010-012	Typical Catch Basin Conversion at Driveway or Crossing
102-0010-013	Curb Inlet Risers for Catch Basin Frame and Cover
102-0010-014	Curb Inlet Catch Basin Frame and Cover
102-0010-015	Roadway Subdrainage Pipe Connection to Catchbasin
Berms	
102-0021-001	Typical Berm Requirements
Sump Details	
102-0025-001	Sump with Pumped Discharge to Surface
102-0025-002	Sump with Pumped Discharge to Storm Sewer
102-0025-003	Sump Pump Retrofit #1
102-0025-004	Sump Pump Retrofit #2 With Pumped Discharge to Surface Plus Backflow Prevention

Source:
http://www.saskatoon.ca/business-development/development-regulation/specifications-standards

City of Saskatoon

Appendix B Tables and Figures

Table B-1
Intensity-Duration-Frequency (IDF) Data

Duration Time		Intensity (mm/h)					
Minutes	**Hours**	**2-yr**	**5-yr**	**10-yr**	**25-yr**	**50-yr**	**100-yr**
5	-	75.6	111	140	182	227	272
10	-	53.2	77.9	98.3	129	160	194
15	-	43.3	64.0	80.9	106	130	157
30	-	28.0	44.3	57.7	79.1	96.3	117
60	1	16.7	29.0	38.6	54.0	67.4	82.4
120	2	10.8	17.7	23.3	31.8	39.8	47.9
360	6	4.82	7.45	9.63	12.8	16.0	19.2
720	12	2.78	4.07	5.12	6.66	8.26	9.85
1440	24	1.56	2.24	2.80	3.64	4.46	5.33

The IDF data are based on a study by university of Saskatchewan and Concordia University in 2020 to incorporate climate change impacts.

Table B-1.1
100-yr, 24-hr and 48-hr Total Rainfall Depth

Duration (hours)	Depth (mm)
24	128
48	201

Table B-1.2
Interpolation Equation
(for 5 min to 24 hr durations)

Intensity (mm/hr) = $A\,T^{i} / (t_d + B)^{c}$

t_d = Duration time (minutes), T = Return period (year), A = 350, B = 4.3 and C = 0.763

Duration(min)	5	10	15	30	60	120	360	720	1440
i	0.323	0.325	0.324	0.360	0.398	0.374	0.348	0.319	0.310

Figure B-1
Intensity-Duration-Frequency (IDF) Curves

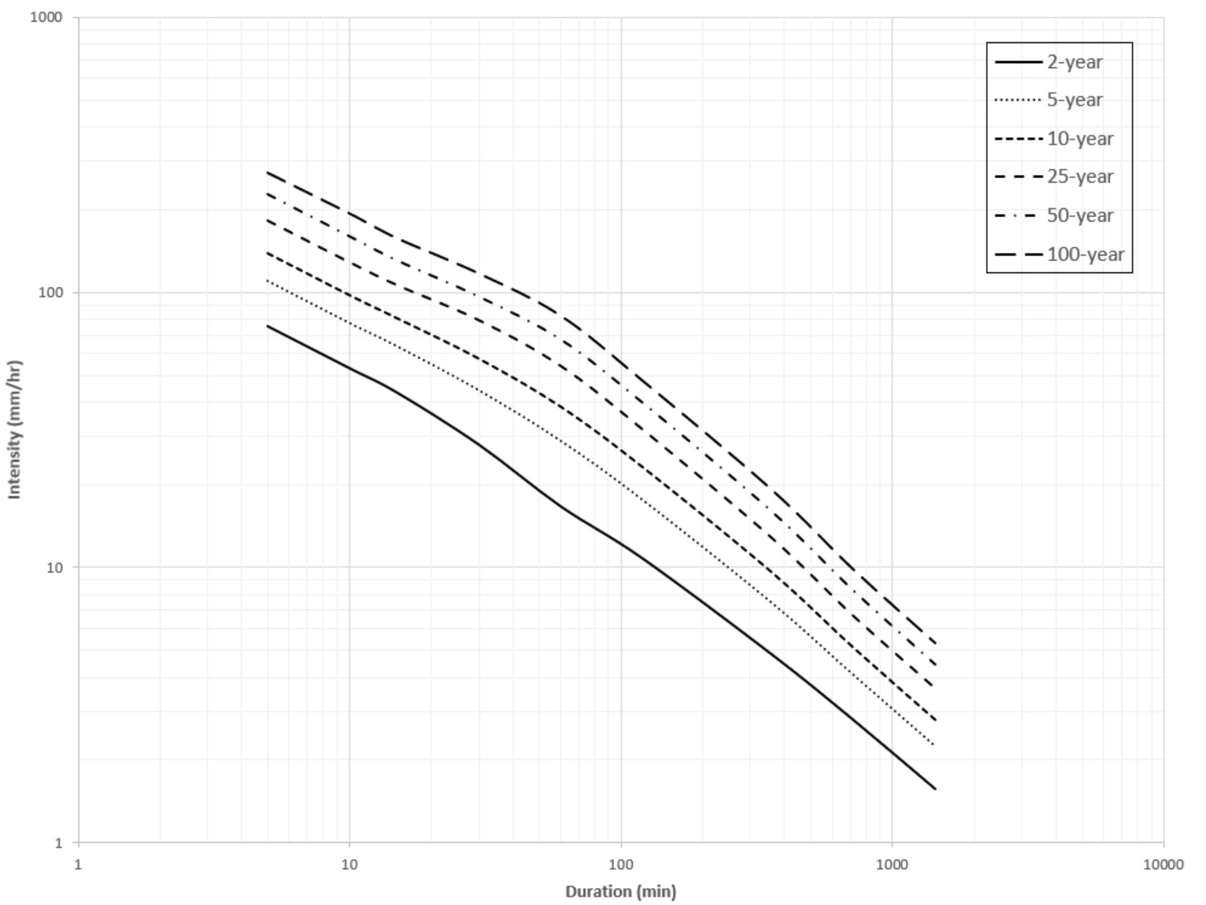

Table B-2
Runoff Coefficients for Urban Areas

Land Use		C (2 year)
Single family residential[1]		0.30
Multi-unit residential, industrial and commercial[2]		0.60
Parks, cemeteries, playgrounds, landscaped areas (lawns, gravel, etc.)		0.10
Unimproved & undeveloped		0.05
Streets, sidewalks, parking lots	Asphalt, concrete, brick, etc.	0.95
	Gravel (compacted)	0.50
Roofs		0.95

Table B-2 Notes:

1. The runoff coefficient for single-family residential includes the streets. The C value for single family residential is currently under review.
2. Higher runoff coefficients may be applicable for parcels with no requirement for internal storm water management system.

Table B-3
Design Storm Hyetograph Distribution

The accumulated rainfall with time using Chicago distribution can be calculated from the following equations (André Luiz Lopes da Silveira, 2016):

-Before peak:
$P_t = Y\ P_{td} – A\ (1/60)\ (t_p - t)/(B + (t_p-t)/\ Y)^C$

-After peak:
$P_t = Y\ P_{td} + A\ (1/60)\ (t – t_P)/(B + (t - t_p)/(1- Y))^C$

Where:
$Y = 0.38$
P_t = Total accumulated rain fall (mm) at time t (min)
P_{td} = Total rainfall for the entire storm duration (mm)
t_p = Time to rainfall peak (= 0.38 t_d)

Using above formula, the rainfall hyetograph distributions for 1-hour and 24-hour rain events are calculated and shown in below tables.

1-Hour

Period Ending (minutes)	Percentage of the Total Rainfall Depth
5	2.7
10	3.4
15	5.0
20	9.7
25	35.4
30	16.6
35	8.3
40	5.6
45	4.3
50	3.5
55	2.9
60	2.6

24-Hour

Period Ending (minutes)	Percentage of the Total Rainfall Depth	Period Ending (minutes)	Percentage of the Total Rainfall Depth	Period Ending (minutes)	Percentage of the Total Rainfall Depth
10	0.2	490	0.9	970	0.3
20	0.2	500	1.1	980	0.3
30	0.2	510	1.3	990	0.3
40	0.2	520	1.6	1000	0.3
50	0.2	530	2.2	1010	0.3
60	0.2	540	4.0	1020	0.3
70	0.2	550	21.2	1030	0.3
80	0.2	560	10.1	1040	0.3
90	0.2	570	4.3	1050	0.3
100	0.2	580	2.8	1060	0.3
110	0.2	590	2.1	1070	0.3
120	0.2	600	1.7	1080	0.2
130	0.2	610	1.5	1090	0.2
140	0.2	620	1.3	1100	0.2
150	0.2	630	1.1	1110	0.2
160	0.2	640	1.0	1120	0.2
170	0.2	650	0.9	1130	0.2
180	0.2	660	0.9	1140	0.2
190	0.2	670	0.8	1150	0.2
200	0.2	680	0.8	1160	0.2
210	0.2	690	0.7	1170	0.2
220	0.2	700	0.7	1180	0.2
230	0.3	710	0.6	1190	0.2
240	0.3	720	0.6	1200	0.2
250	0.3	730	0.6	1210	0.2
260	0.3	740	0.6	1220	0.2
270	0.3	750	0.5	1230	0.2
280	0.3	760	0.5	1240	0.2
290	0.3	770	0.5	1250	0.2
300	0.3	780	0.5	1260	0.2
310	0.3	790	0.5	1270	0.2

320	0.3	800	0.4	1280	0.2
330	0.3	810	0.4	1290	0.2
340	0.3	820	0.4	1300	0.2
350	0.4	830	0.4	1310	0.2
360	0.4	840	0.4	1320	0.2
370	0.4	850	0.4	1330	0.2
380	0.4	860	0.4	1340	0.2
390	0.4	870	0.4	1350	0.2
400	0.4	880	0.4	1360	0.2
410	0.5	890	0.4	1370	0.2
420	0.5	900	0.3	1380	0.2
430	0.5	910	0.3	1390	0.2
440	0.6	920	0.3	1400	0.2
450	0.6	930	0.3	1410	0.2
460	0.7	940	0.3	1420	0.2
470	0.7	950	0.3	1430	0.2
480	0.8	960	0.3	1440	0.2

Figure B-3
Design Hyetograph of 100-yr, 48-hr storm

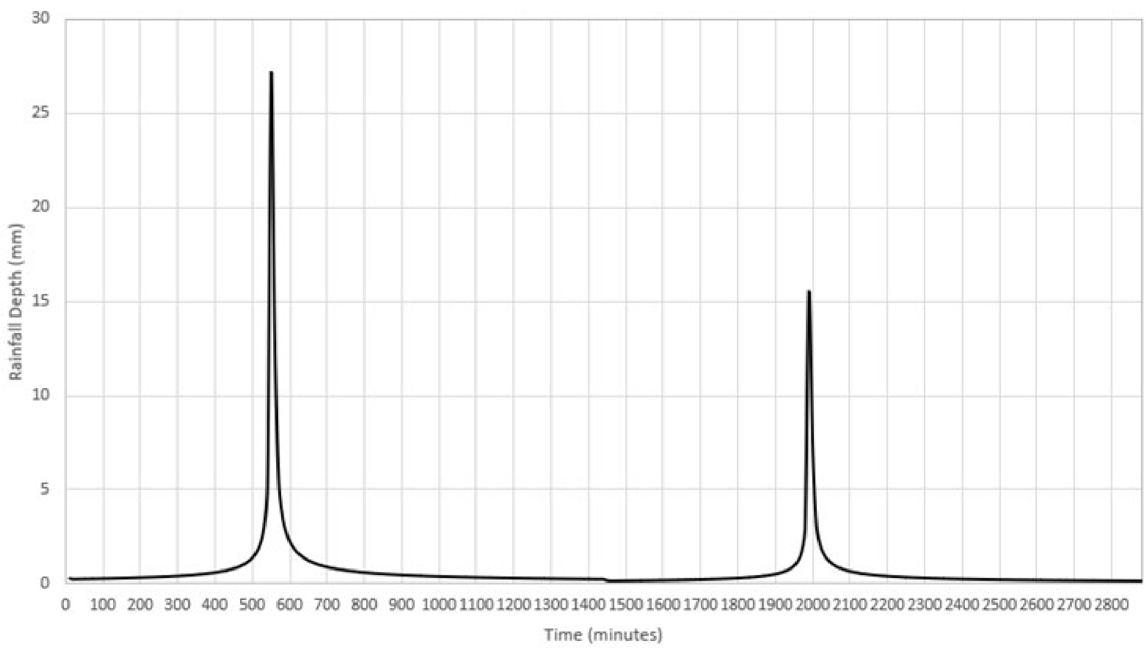

Table B-4
Rainfall Amounts for the Historical Event of June 24, 1983[1,2]

Period End (hr:min)	Rainfall During Period (mm)	Period End (hr:min)	Rainfall During Period (mm)	Period End (hr:min)	Rainfall During Period (mm)	Period End (hr:min)	Rainfall During Period (mm)
00:10	10.7	06:10	0	12:10	0	18:10	0
00:20	0.1	06:20	0	12:20	0	18:20	0
00:30	0.1	0:630	0	12:30	0	18:30	0.1
00:40	0.2	0:640	0	12:40	0	18:40	0.3
00:50	0.5	0:650	0	12:50	0	18:50	0
01:00	0.3	07:00	0	13:00	0	19:00	0
01:10	0.2	07:10	0	13:10	0	19:10	0.2
01:20	0.6	07:20	0	13:20	0	19:20	0.2
01:30	0.2	07:30	0	13:30	0	19:30	0.4
01:40	0.2	07:40	0	13:40	0	19:40	0.4
01:50	0.4	07:50	0	13:50	0	19:50	0.6
02:00	0.3	08:00	0	14:00	13.8	20:00	0.4
02:10	0	08:10	0	14:10	16.5	20:10	0.4
02:20	0	08:20	0	14:20	20.6	20:20	0.6
02:30	0.2	08:30	0	14:30	19.4	20:30	0.2
02:40	0.2	08:40	0	14:40	2.9	20:40	0.4
02:50	0.1	08:50	0	14:50	1.2	20:50	0.4
03:00	0	09:00	0	15:00	0	21:00	0.2
03:10	0.1	09:10	0	15:10	0.8	21:10	0
03:20	0	09:20	0	15:20	0.4	21:20	0
03:30	0	09:30	0	15:30	0.3	21:30	0
03:40	0.1	09:40	0	15:40	0.4	21:40	0
03:50	0	09:50	0	15:50	0.4	21:50	0
04:00	0.1	10:00	0	16:00	0.2	22:00	0
04:10	0	10:10	0	16:10	0.2	22:10	0
04:20	0	10:20	0	16:20	0	22:20	0
04:30	0	10:30	0	16:30	0	22:30	0
04:50	0	10:50	0	16:50	0	22:50	0
05:00	0	11:00	0	17:00	0	23:00	0
05:10	0	11:10	0	17:10	0	23:10	0
05:20	0	11:20	0	17:20	0	23:20	0

Period End (hr:min)	Rainfall During Period (mm)	Period End (hr:min)	Rainfall During Period (mm)	Period End (hr:min)	Rainfall During Period (mm)	Period End (hr:min)	Rainfall During Period (mm)
05:30	0	11:30	0	17:30	0	23:30	0
05:40	0	11:40	0	17:40	0	23:40	0
05:50	0	11:50	0	17:50	0	23:50	0
06:00	0	12:00	0	18:00	0	24:00	0

Source: Meteorological Service of Canada (formerly Atmospheric Environment Services), Environment Canada.

Table B-4 Notes:

1: Time 0:00 of this hyetograph corresponds to 3:00 a.m. of the actual storm.

2: A total of 96.5 mm fell on June 24; 14.6 mm before 7:00 a.m. and 81.9 mm after 5:00 p.m.

Table B-5
XPSWMM Modeling Parameters

Sub-catchment Parameters[1]		
$W = 100\ A^{1/2}$, W = width (m) and A = area (ha) Slope = 0.02		
Soil Infiltration Parameters[2]		
Depression storage (mm)	Pervious	2.5
	Impervious	0.55
Manning's n	Pervious	0.25
	Impervious	0.013
Zero detention (%)	30	
Maximum infiltration rate (mm/hr)	125	
Minimum infiltration rate (mm/hr)	15	
Decay rate (1/s)	0.0025	
Maximum infiltration volume	0	

Table B-5 Notes:
1. Actual measured values can be used if available
2. Double ring test may be performed to obtain site-specific infiltration rates.