City of PICKERING

Stormwater Management Design Guidelines

July 2019

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1.0 General Policies and Principles

1.1 Introduction

The Stormwater Management Design Guidelines (Guidelines) were created for developers, engineers and architects preparing development plans in the City of Pickering. The goals of the Guidelines are to provide the technical tools and guidelines necessary to comply with the City's stormwater management (SWM) requirements and infrastructure design standards.

These Guidelines address a set of stormwater management facilities (SWM facilities) and practices to control the stormwater related impacts of development and redevelopment in the City. SWM facilities should be understood and incorporated into development designs because they efficiently achieve both development and environmental goals in the most cost effective manner.

1.2 Design Responsibilities

The Guidelines discuss minimum design recommendations and provide information to assist the designer in complying with the City's SWM criteria. When unusual circumstances or complex problems arise, the applicant and applicant's designer (engineer, wetland specialist, fisheries biologist, surveyor, or landscape architect) are responsible for identifying such conditions and notifying the appropriate review agencies. In such cases, the applicant and applicant's designer shall propose an alternative solution consistent with good planning, engineering practices, and scientific principles, and the designer or applicant shall obtain approval of the change from City of Pickering before continuing with the design. Use of the Guidelines or issuance of a permit does not release the designer from design responsibilities.

These Guidelines are not intended to specify limitations on the creative design process. Designers have flexibility in devising solutions; however, the City must approve the final SWM plan. The analytical procedures and techniques presented herein are consistent with available data and principles of hydrology and hydraulics as they are currently understood. Procedures selected for use by the City are from commonly used and recognized sources. Users of the Guidelines are responsible for the integrity and design of the various facilities proposed.

1.3 The Need for Stormwater Management

The impacts from development occur both during construction and after the development is complete. The conversion of pervious land to impervious surfaces results in increased rate and volume of stormwater runoff, reductions in groundwater recharge and reduction of evapotranspiration. These new impervious surfaces change the hydrologic characteristics of the landscape by reducing infiltration into the soil and evapotranspiration from vegetation which results in a dramatic increase in the rate and volume of stormwater runoff (See Figure 1). New impervious surfaces, compaction of soils, and loss of native vegetation reduces the amount of precipitation that infiltrates into the ground.

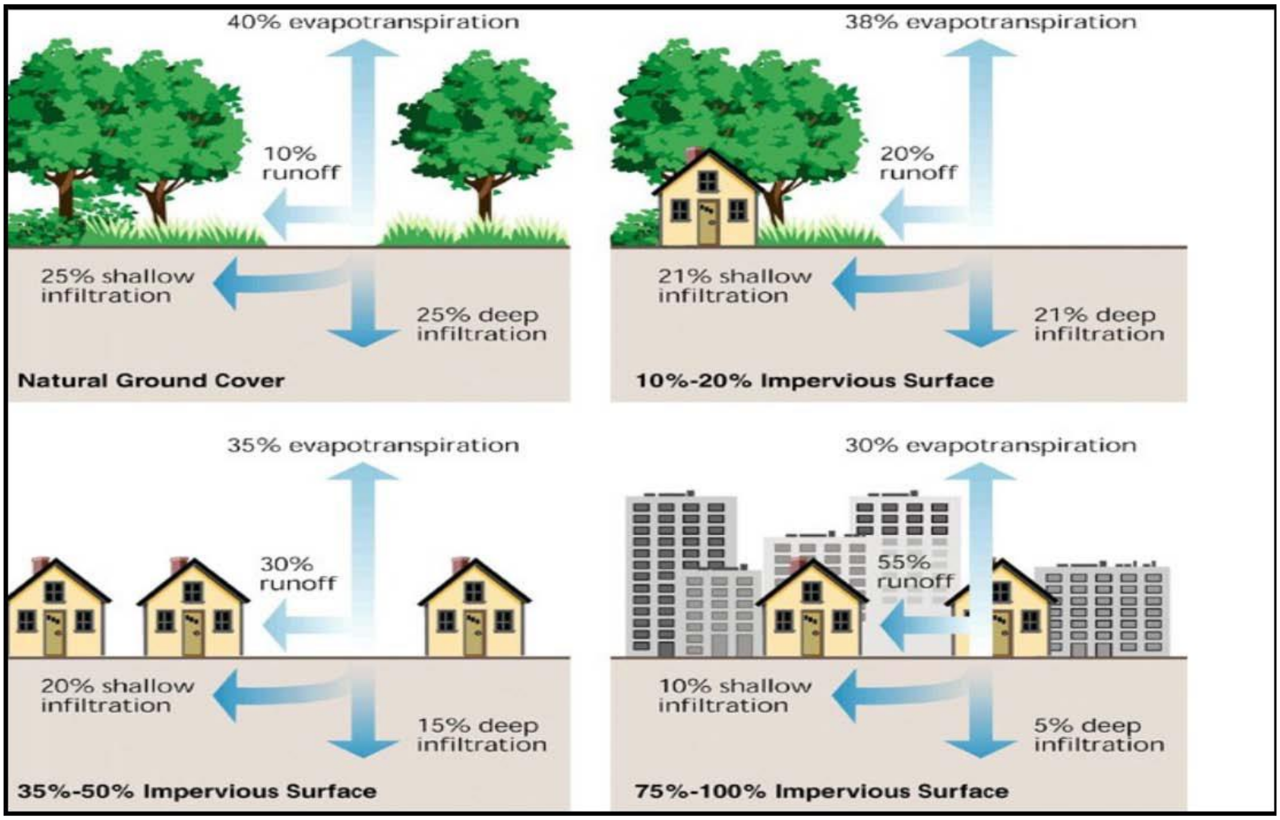


Figure 1 - Land Use Change and the Hydrologic Cycle (US EPA, 2007)

Uncontrolled, the impacts of development on stormwater runoff can lead to increased flooding, degraded water quality, stream channel erosion, hydrologic modifications, and destruction of sensitive habitats and landscapes. Properly designed and implemented SWM facilities can mitigate these impacts.

1.4 Stormwater Management Policies and Principles

It is the policy of the City to encourage and promote programs that:

- Control and, to the extent practical, eliminate water, soil, noise and air pollution to safeguard the natural and human environment.
- Protect and improve surface water quality, wherever possible.
- Protect groundwater quality and quantity.
- Provide stormwater management facilities that are efficient, and minimize life cycle costs.
- Maintain the natural hydrologic cycle and function of the watersheds through a range of mechanisms through implementation of Low Impact Development (LID) stormwater management practices and principles.
- Prevent increased risk of flooding and stream erosion.
- Use the treatment train approach to reduce runoff volume and to treat stormwater runoff on-site through the use of source, conveyance and end-of-pipe controls.

The following represents a general overview of the guiding principles and parameters for the design of stormwater management and drainage systems in the City of Pickering:

- All newly developing or re-developing areas must assess their potential impacts on local and regional flooding and mitigate accordingly.
- All stormwater system designs for water quality treatment shall be in accordance with the most current Ministry of the Environment Stormwater Management Planning and Design Manual (MOE SWM Manual) and shall use the treatment train approach.
- Enhanced water quality treatment shall be provided as defined by the MOE SWM Manual.
- Design shall consider the entire uncontrolled drainage area and external flows.
- Minor Systems shall be sized to capture and convey the 5 Year Storm.
- Major Systems shall be sized to capture and convey the Regulatory Storm to a safe outlet without flooding adjacent properties and should provide a minimum of 300 mm of freeboard from the maximum water surface elevation of the major system flow path to the minimum opening of structures.
- Hydraulic Grade Line in the storm sewer for the 100 year storm is a minimum of 300 mm below the basement elevation i.e., the underside of basement slab elevation.
- Drainage from Public Lands shall be contained within the Public ownership, and shall not discharge into private drainage systems.

1.5 Environmental and Municipal Land Use Planning

1.5.1 Introduction

The City of Pickering storm drainage and SWM policies and design guidelines presented herein are intended as a guide to provide a solid engineering basis for storm drainage and SWM facility design, to establish uniform guidelines of minimum standards, and to improve the processing of site plan and plan of subdivision applications.

Changes and revisions may be made to these policies and guidelines from time to time and it is the responsibility of the Owner or the Owner's Consulting Engineer to obtain and make use of the latest available version.

1.5.2 Environmental and Land Use Planning

The environmental and land use planning process has evolved over time to enable a streamlined review process and to ensure that qualified input and representation from the agencies, public and consultants is provided at the appropriate time. A flow chart illustrating the Environmental Planning Process for the City of Pickering is provided in . The flow chart shows the different stages of the planning process, the interrelation between the Environmental Planning Process and the Municipal Land Use Planning Process, and the input from the public and approval agencies. The following sections describe the Urban Drainage/Environmental Plans that are required at different stages of the overall planning process.

1.5.3 Watershed Plan

Planning at the watershed level integrates resource management, land use planning and land management practices and is generally of value for addressing environmental issues associated with studies on the scale of an Official Plan. The study provides an overall picture of how land use practices have influenced environmental resources and how land use changes should take place without causing adverse impacts to the watershed resources.

Watershed Plans have been completed for all the watersheds in Pickering as listed below:

- Rouge River (TRCA, 2007)
- Petticoat Creek (TRCA, 2011)
- Duffins Creek (TRCA, 2003)
- Carruthers Creek (TRCA, 2003)
- Frenchmans Bay Stormwater Management Masterplan (City of Pickering, 2009)
- Lynde Creek (CLOCA, 2012)

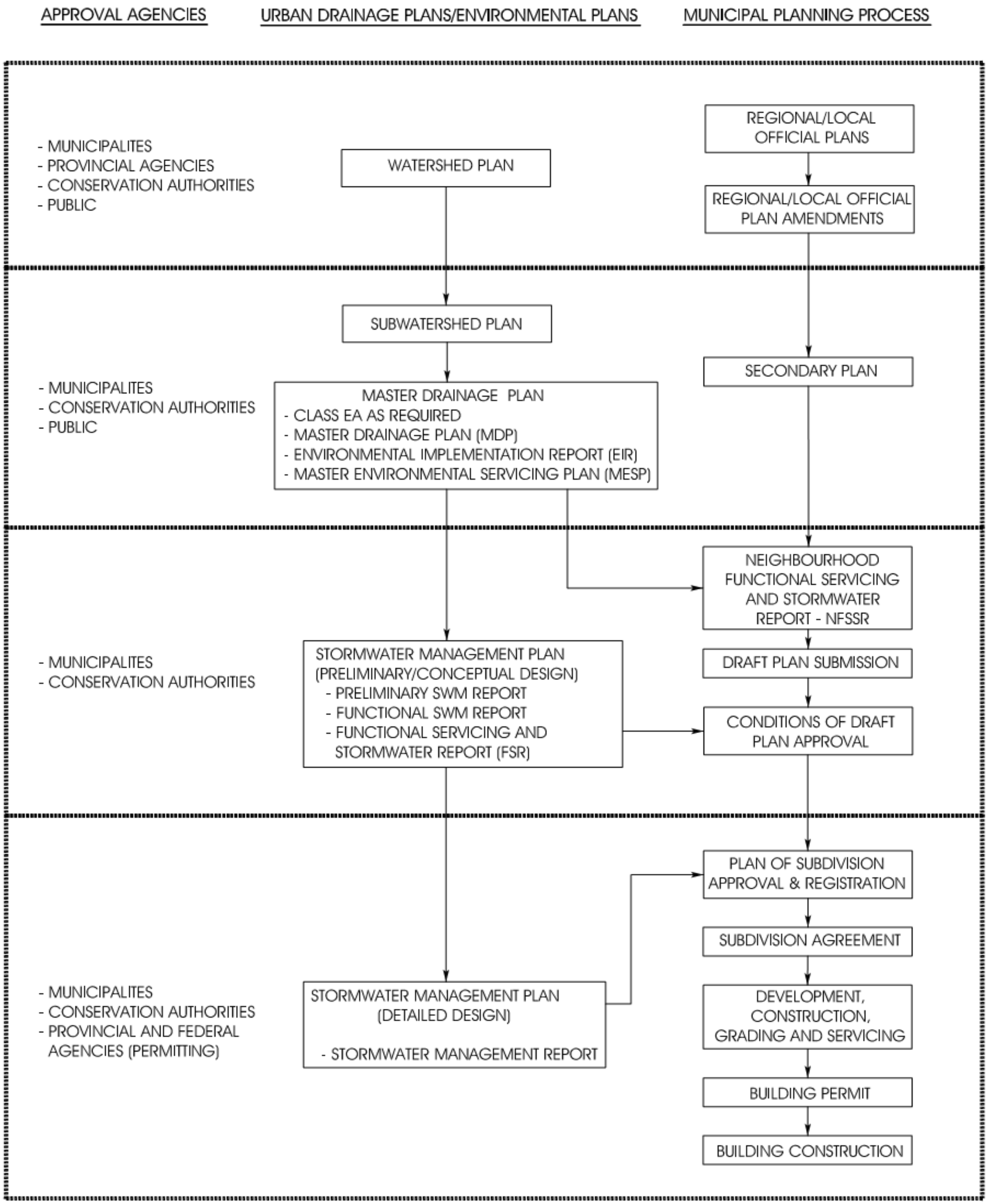


Figure 2 - City of Pickering Environmental Planning Process

1.5.4 Master Environmental Servicing Plan

Master Environmental Servicing Plans (MESP) are completed in support of Official Plan Amendments. The MESP demonstrates how development can proceed in accordance with the requirements and criteria established in the watershed plan in addition to other environmental constraints.

Details provided in the plan include a review of existing information and existing environmental constraints, the establishment of constraint and opportunity mapping and the development of a preferred environmental and SWM strategy for the lands within the plan study area.

1.5.5 Neighbourhood Functional Servicing and Stormwater Reports

Neighbourhood Functional Servicing and Stormwater Reports (NFSSR) are completed in support of draft plan approval and describe the proposed water supply, sanitary servicing, storm sewer drainage system and SWM facilities. NFSSRs assist in co-coordinating the delivery of services and infrastructure, allocation of development priority, layout of roads and the location and configuration, character, size and urban form of parks, institutional, commercial and industrial sites and layout/function of open space corridors, valleylands, woodlots and other natural features including SWM facilities. The NFSSR confirms how the servicing and development conforms with the requirements from the MESP in addition to other relevant guidelines and City standards.

The City supports the treatment train approach to SWM and the NFSSR presents the best opportunity to develop a comprehensive SWM strategy composed of source, conveyance and end-of-pipe facilities. Preliminary sizing of storm drainage systems and SWM facilities should be completed at this stage and should use conservative assumptions to ensure sufficient lands are set aside.

1.5.6 Functional Servicing and Stormwater Reports

Functional Servicing and Stormwater Reports (FSSR) are the same as the NFSSRs but at a smaller scale.

1.5.7 Stormwater Management Report

The Stormwater Management Report is completed at the detailed design stage and is required for Plan of Subdivision Approval and Registration and describes how the requirements set out in the NFSSR have been fulfilled. A Stormwater Management Report should be submitted for every SWM facility in the subdivision.

The Stormwater Management Report provides details and supporting calculations associated with the detailed design of the minor and major drainage system and the required source, conveyance and end-of-pipe controls required to achieve the criteria established in the NFSSR. It also provides design details for infrastructure to confirm that the design conforms to City standards. The Stormwater Management Report also includes the Monitoring Plan and the Operations and Maintenance plan.

1.5.8 Municipal Class Environmental Assessment

The Municipal Class Environmental Assessment applies to municipal infrastructure projects including roads, water and wastewater projects. It should be noted that the definition of wastewater in the MEA document includes stormwater. Depending on the potential environmental impact of projects undertaken by the municipality, the project is classified according to the following schedules that must be adhered to as part of the Municipal Class EA process:

Schedule A

Generally includes normal or emergency operational and maintenance activities. The environmental effects of these activities are usually minimal and, therefore, these projects are pre-approved and may proceed directly from problem identification (Phase 1) to detailed design and construction (Phase 5).

Schedule A+

These projects are pre-approved; however, the public is to be advised prior to project implementation. The manner in which the public is advised is to be determined by the proponent. Similar to Schedule A projects, Schedule A+ projects may proceed directly from problem identification (Phase 1) to detailed design and construction (Phase 5).

Schedule B

Generally includes improvements and minor expansions to existing facilities. There is the potential for some adverse environmental impacts and, therefore, the proponent is required to proceed through a screening process including consultation with those who may be affected. Schedule B projects may proceed directly to detailed design and construction (Phase 5) following the completion of problem identification (Phase 1) and the analysis/evaluation of alternative solutions and public consultation (Phase 2) subject to no Part II Order being requested by the Public and granted by the Minister. Should a Part II Order be granted, the project may be elevated to a Schedule C or an Individual Environmental Assessment, or the project may be abandoned.

Schedule C

Generally includes the construction of new facilities and major expansions to existing facilities. These projects have the potential for significant environmental impact and require additional analysis of design concepts for the preferred solution (Phase 3) and the completion of an environmental study report (Phase 4) as per the environmental assessment planning process outlined in the Municipal Class EA document (MEA, September 2007). Schedule C projects may proceed directly to detailed design and construction (Phase 5) following the completion of Phase 1 through Phase 4 subject to no Part II Order being requested by the Public and granted by the Minister. Should a Part II Order be granted, the project may be elevated to an Individual Environmental Assessment or the project may be abandoned.

Master Plans

Schedule A, A+, B and C projects address the planning and design process whereby municipal infrastructure works are planned on a project by project basis. The Master Planning process enables several related projects to be grouped together which is typically more time and cost efficient for municipalities. As a minimum, the Master Planning Process should address Phase 1 and Phase 2 in the planning and design process of the Class EA. The Master Planning Process identifies requirements for any of the grouped projects within the Master Plan to proceed beyond Phase 2 classified either as a Schedule B, C or Individual EA. Any grouped projects that are classified as Schedule B during the Master Planning Process, subject to no Part II Order being requested by the Public and granted by the Minister, are cleared to proceed to detailed design and construction (Phase 5). Any grouped projects that are classified as Schedule C during the Master Planning Process must first complete Phase 3 and Phase 4 of the Municipal Class EA process prior to proceeding to detailed design and construction (Phase 5), subject to no Part II Order being requested by the Public and granted by the Minister.

2.0 Legislation – Acts and Regulations

The SWM policies and design guidelines provided in this document were developed in accordance with legislation and acts for:

- Watercourses and Existing Infrastructure (i.e., Culverts and Bridges, Roads)
- Erosion and Sediment Control
- Flood Damage Control
- Pollution Prevention
- Fisheries

When developing in the City of Pickering, the following partial list of key acts and regulations may apply:

Federal Acts and Regulations

- *Federal Fisheries Act*
- *Species at Risk Act (SARA)*
- *Navigable Waters Protection Act* (*NWPA*)
- *Canadian Environmental Assessment Act*

Provincial Acts and Regulations

- *Conservation Authorities Act (incl. Ontario Regulation 166/06)*
- *Regulation of Development, Interference with Wetlands and Alterations to Shorelines and Watercourses*
- *Endangered Species Act*
- *Drainage Act*
- *Provincial* Policy Statement
    - Natural Hazard Land Policies
    - Water Quality and Quantity Policies
- *Lakes and Rivers Improvement Act*
- *Environmental Protection Act*
- *Ontario Water Resources Act*
- *Ontario Environmental Assessment Act*
- *Planning Act*
- *Public Land Act*

- *Municipal Act*
- *Greenbelt Act*
- *Oak Ridges Moraine Conservation Act*
- *Ontario Planning and Development Act (Seaton)*
- *Places to Grow Act*
- Provincial Secondary Land Use Policy
- MTO Drainage Management Policy
- Elements of Common Law
  - Natural Watercourses (Riparian Rights and Obligations)
  - Surface or Sheet Flow
  - Subsurface Flow

Local Regulations/By-laws

- Municipal Zoning By-law for the area of interest
- City of Pickering Fill and Topsoil Disturbance By-law
- City of Pickering Noise By-law
- City of Pickering Tree Protection By-law

3.0 Stormwater Drainage System Design Guidelines

Well-designed stormwater conveyance systems are critical for ensuring that stormwater is safely conveyed away from roads and structures to appropriate drainage outlets. The City strives to ensure that the drainage systems for new developments are robust and designed to the highest standards of performance.

For greenfield development a dual drainage system analysis shall be completed to demonstrate that the City's requirements for major and minor system conveyance and the hydraulic grade line are being met.

For infill/redevelopment sites the proponent shall demonstrate through a dual drainage system analysis that the downstream minor and major system has sufficient capacity to safely accommodate design flows from point of connection of the development site to an existing outfall.

This section discusses the policies and design guidelines applicable to the storm drainage system including foundation drains, the minor system (sewers), the major system (roads and swales), bridges and culverts, watercourses and easements and buffers. When constructing on private property, construction materials and practices must be in accordance with the Ontario Building Code (OBC) and the City of Pickering Standards.

3.1 Minor System

The minor system conveys urban drainage from relatively "minor" storms having a return period of 5 years. These works typically consist of drainage pipes, catchbasins, roadway gutters and swales, enclosed conduits and roof leaders. Their purpose is to prevent frequent flooding of road surfaces, parking lots and parks.

The City will not allow development to proceed until adequate provision, in the form of storm sewers, has been made available. Rural development will also require adequate provision for storm drainage; however it may not require storm sewers.

The minor system, comprised of street gutters, catchbasins and storm sewers, shall be designed to:

- Convey the 1 in 5 year flow without exceeding 80% capacity.
- Flow in a subcritical condition – supercritical flow in sewers will not be allowed.
- Ensure the Hydraulic Grade Line (HGL) during the 100 year storm is a minimum of 300 mm below the basement elevation i.e., the underside of basement slab elevation.

If the outlet of the storm sewer system is submerged during the 5 year and 100 year events, the hydraulic analysis used to size the pipes should account for backwater effects to ensure that the City's conveyance and HGL requirements are met. For sewersheds larger than 40 hectares, or with complicated hydraulics, a dynamic computer model must be used.

In areas where the capacity of the receiving storm sewer system is constrained, the site will still need to provide the required level of service for the storm sewer system on-site. However, there will be an additional requirement that the capacity of the existing storm sewer system is assessed to determine the required release rate from the site to ensure that there are no impacts to the receiving system. If the allowable release rate is less than the 1 in 5 year flow, the site will be required to provide on-site storage to control the minor system flow to the capacity of the existing, receiving storm sewer system.

In areas where major storm drainage capture is required, the receiving storm sewer must be sized to convey the 100 year storm event. Notwithstanding, storm sewers designed to convey the 1 in 5 year flow will be required in all other cases.

Hydraulic analysis of the proposed and existing storm sewer system shall provide hydraulic grade lines for the 1 in 5 year standard and 1 in 100 year standard.

3.1.1 Storm Sewer Design

The following information shall be used in the hydraulic analysis of the storm sewer system. The design of storm sewers shall be in accordance with the City of Pickering Engineering Services Design Standards – Storm Sewer Services.

Design Flow

Flows for sizing storm sewers shall be determined using the Rational Method, Pickering's IDF data (Table 12), Pickering's runoff coefficients and Manning's equation for sewershed areas smaller than 40 hectares provided that the outlet is not submerged by the receiving system. Refer to Section 6.0 for the required Analytical Methods to be used in the design of stormwater infrastructure.

Pipe Capacities

Sewer capacities shall be computed using the Manning's Equation. Storm sewers shall be designed to convey the 1 in 5 year flow at 80% capacity flowing in a subcritical condition. Refer to Section 6.0 for the required Analytical Methods to be used in the design of stormwater infrastructure.

In addition, the proponent is to ensure that adequate overland flow capacity is available in the development and in the receiving major system.

Roughness Coefficient

For a new storm sewer design, the value of the Manning's roughness coefficient "n" will be:

Table 1 - Manning's Roughness Coefficients for Pipes

Pipe Material	Manning's Roughness "n"
Concrete	0.013
Polyvinyl Chloride	0.013
High Density Polyethylene	0.013

Pipe Size

The minimum allowable size for a storm sewer will be 300 mm diameter.

Minimum Velocity

The minimum full bore velocity permitted in storm sewers will be 0.8 m/s.

Maximum Velocity

The maximum full bore velocity permitted in storm sewers will be 5 m/s.

Where velocities in excess of 3 m/s are proposed, additional design factors shall be taken to protect against pipe displacement, scouring, erosion, and hydraulic jumps.

Minimum Grades

The minimum grade on storm sewers shall be half a percent (0.5%). The minimum slope of the upstream leg of all storm sewers shall be one percent, unless future developments upstream cannot accommodate this grade.

For replacement of pipe sections of existing storm sewer systems, a minimum flow velocity of 0.8 m/s shall be achieved.

Pipe Material

Both rigid and flexible pipe are permitted in the construction of storm sewer systems including municipal service connections and catchbasin leads. These materials include reinforced concrete (CONC), polyvinyl chloride (PVC) and high density polyethylene (HDPE). However, the bedding design must be compatible with the type of pipe material used.

Table 2 - Pipe Size and Pipe Materials

If the diameter is	Then the material to use is
Less than or equal to 375 mm	PVC/HDPE
Equal or greater than 450 mm	CONC or PVC

Rigid pipe is recommended in areas of high utility congestion, when bedding may be undermined in the future.

For more information regarding acceptable materials, please refer to the City of Pickering’s Engineering Services Design Standards – Storm Sewer Services.

Drop Structures

External drop pipes will be provided when the difference in invert elevations is greater than 600 mm. The external drop pipe will be one size smaller than the sewer line – minimum 200 mm diameter. The alternative of providing a deeper storm sewer instead of a drop maintenance hole may be considered at the City’s discretion. Refer to City Standard P-110. Where flow overshoots the standard drop connection, refer to City Standard P-111.

Hydraulic Losses at Maintenance Holes

Suitable drops will be provided across maintenance holes to compensate for the energy losses due to the change in flow velocity and to accommodate the difference in depth of flow in the upstream and downstream sewers. When the pipe size does not change through a maintenance hole and the upstream flow velocity does not exceed 1.5 m/s, the following allowances will be made to compensate for hydraulic losses:

Table 3 - Hydraulic Losses for Alignment Changes

If alignment change is	Then drop required is
Straight Run	Grade of sewer or 30 mm
15 – 45 Degrees	30 mm – MOE minimum 75 mm – preferred
45 – 90 Degrees	60 mm – MOE minimum 150 mm preferred
Junctions and Transitions[a]	MOE Calculations

[a] For all junctions and transition maintenance holes and when the upstream flow velocity exceeds 1.5 m/s, the drop required will need to be calculated using the MOE Guidelines; “Hydraulic Calculations for Junction and Transition Maintenance Holes”. Calculations for hydraulic losses will be included in the design submission.

The engineer shall adhere to the following guidelines:

- Endeavor to keep entrance and exit velocities equal. In order to reduce the amount of drop required, the engineer will try to restrict the change in velocity from one pipe to another in a maintenance hole to less than 0.6 m/s.
- No acute interior angles will be allowed.
- No decrease in pipe diameter from a larger size upstream to a smaller size downstream will be allowed, regardless of an increase in grade.
- When an increase in pipe size occurs at the downstream side of the storm maintenance hole, match obvert elevations of the incoming and outgoing pipes or have incoming pipe obverts higher than outgoing pipe obverts.

Changes in Pipe Alignment

The maximum change in direction for pipe sizes 675 mm and larger is 45 degrees. For 675 mm and larger diameter pipes where the change in direction is greater than 45 degrees, additional maintenance holes 1200 mm in diameter will be required to reduce the angle.

Minimum Size and Grades

The actual size of the storm service connection required for non-residential, commercial, institutional, and high rise condominiums is determined by the maximum flow permitted from the development. The minimum diameter and grade of a storm service connection is 150 mm diameter at 2 percent slope. Where the storm service connection is required to be an orifice tube, smaller pipe diameters may be acceptable.

Control Maintenance Hole

The City requires a control maintenance hole located on the property of the owner, as close to the property line as possible. This requirement will apply to all multi-family, commercial, industrial and institutional blocks.

Catchbasins

Catchbasins will be provided to collect drainage from both pervious and impervious areas. The spacing and design of catchbasins shall be as per the City of Pickering's Engineering Services Design Standards. In designing the stormwater collection system the engineer will ensure that the number of catchbasins connected to each section of sewer is appropriate so that the minor system is not overloaded causing issues with the hydraulic grade line in the receiving system.

Minor System Outlet Structures

New outfalls discharging to watercourses shall be designed to prevent erosion. They shall be blended into the natural surroundings, in an aesthetically pleasing manner to the greatest extent possible. Pipe exit velocities shall not impart additional erosion potential to the streambed and banks. In addition, the outfall shall be adequately protected from erosive forces in the receiving watercourse to prevent scouring and undermining. Outfalls shall not discharge at the top of valley walls.

The proponent should position the outlet to minimize the angle at which flow from the outfall ties into the watercourse. Outfall channels should join a watercourse at no more than 90 degrees, with angles less than 45 degrees preferred. Wherever possible, outfalls should be located in geomorphically stable locations to protect against impacts from anticipated planform adjustment of the watercourse. Storm sewer outfalls to regulated watercourses require a permit from the Conservation Authority. Storm sewer outfall design is to be submitted to the City as part of the full engineering submission.

Outfalls to natural watercourses should discharge at or above the average water elevation of the watercourse. If high water levels cause the submergence of the outlet, the impact of the submergence on the sewer system must be assessed in the hydraulic design of the storm sewer. The invert of the outlet shall be above the 25 year flood elevation of the receiving channel.

Storm sewer outfalls discharging directly to Lake Ontario will need to consider the potential problem of dynamic beaches and the potential obstruction of the outlet (MNR, 2003). The outfall's invert should be located above the 100 year lake elevation of 75.7 m. The proponent shall consult with a professional coastal engineer and provide appropriate mitigation measures.

An access road with a minimum width of 4 m and cross fall of 2% should be provided to outfalls (refer to City Standards P-1007, P-1008, P-1009 and P-1010). Should the outfall be within a fenced area, gate access shall be provided.

Outfalls shall be provided with safeguards to prevent entry by unauthorized personnel into the outfall. Current City Standards use the Ontario Provincial Standard Drawings (OPSD), which should be followed to determine what outfall sizes require grates to prevent unauthorized entry. Grates shall be installed with means for locking. Provisions must be made for opening or removing the grate for cleaning purposes. Grates should be designed to break away or swing open under extreme hydraulic loads due to blockage.

Outfalls should be made as safe as possible by utilizing fencing along the headwalls and wingwalls to prevent accidental falls. Submerged outfalls need to be specifically designed to withstand freeze-thaw cycles and ice dams.

3.1.2 Foundation Drains

In order to minimize the flow rate from foundation drains, piezometer tests shall be completed prior to design and construction to determine the seasonal high water level. Foundation elevations should then be set 500 mm higher than the seasonally high water table. Where the anticipated flow from sump pumps will be considered a nuisance as deemed by the City, the City may request that Options 2 and 3 be implemented. Foundation drains shall have an accessible outlet for maintenance/cleanout.

Foundation drain collector systems shall be designed on the basis of a continuous flow rate of 0.075 litres per second per residential lot plus infiltration. The minimum foundation drain collector diameter shall be 200 mm. Material and bedding standards applicable to foundation drain collectors shall be in accordance with Pickering Standard Drawings.

Foundation drains shall be connected to the storm sewer system. The City will allow for an approved outlet which could include the storm sewer system. Where grades do not permit connections or where the HGL criteria cannot be achieved to protect basements against flooding, the following alternatives are acceptable to the City:

Option 1: Gravity drain or sump pump with discharge to third pipe (foundation drain collector – FDC)

A third pipe (FDC) shall be constructed in the right-of-way (ROW) to collect foundation drain flow by gravity (or using a sump pump if grades do not permit) and to convey the flow to a nearby watercourse or other acceptable water body and/or LID facility. Similar to the option above, an FDC eliminates the risk of basement flooding and surface discharge and nuisance flooding.

Option 2: Sump pump with discharge of foundation drain flow to storm sewer extension at surface or subsurface

Lots shall be constructed with a storm sewer extension from the storm sewer system to the surface or subsurface adjacent the building. Flow collecting in the foundation drain shall be pumped to the surface (or subsurface) using a sump pump and into the storm sewer extension and then conveyed to the storm sewer. A benefit of this configuration is the ability to discharge flow from foundation drains into the storm sewer while eliminating the risk of basement flooding and avoid surface discharge and nuisance flooding.

Option 3: Sump pump with discharge of foundation drain flow to ground surface

Flow collecting in the foundation drain shall be pumped to the surface using a sump pump and then conveyed overland via lot drainage to the street or surface drain.

Infill development projects will consider direct connection of the roof leaders and foundation drains on a site specific basis, but this generally will not be permitted. For those projects, there will be no direct connection of foundation drains or roof leaders to the minor system. Sump pumps will be required in the basements with the approval of the Director, Engineering Services.

3.2 Major System

Flows in excess of the minor system capacity (i.e., during periods of surcharging or higher intensity events) are referred to as the major system flow. The major system inherently comprises the minor system, as well as the overland route followed by runoff not captured by the minor system (i.e., either due to excessive flow or operational failures). Common elements of the major system include roadways, swales, ponds, dedicated blocks, outfall channels, natural streams and valleys. Major system flow paths shall be in public ownership. In extenuating circumstances major system flow paths may be allowed on private property provided that an easement in favour of the City of Pickering is provided at the Owner's cost.

The major system shall safely convey drainage from the Regulatory Storm, defined as the larger of the 100 year storm or the Regional Storm, to an appropriate outlet without causing damage to private property and with minimum inconvenience to the public. Calculations and model results (i.e PCSWMM) must be provided to demonstrate that the overland flow route has sufficient capacity to convey this flow. Where the major system is receiving flow from a stormwater management facility it must be sized to convey the flow from the uncontrolled Regulatory storm (i.e., the peak flow into the facility). The extent and top elevation of the major system flow path are to be shown on the grading plan drawings.

In all cases, the proponent of a development site shall investigate and determine the direction and hydraulic capacity of the conveyance path for the existing major system flow from the site to a watercourse. The purpose of this investigation is to determine if a suitable overland flow route of sufficient hydraulic capacities exists, which is acceptable to the City.

If the proposed major system overland flow route is accepted by the City, storm runoff is allowed to discharge off-site. If no approved or adequate overland flow route exists, then all events up to the Regulatory Storm must be detained on-site and released at the allowable release rate into the minor system.

The overland flow (major) system within the subject development site shall be designed to accommodate and/or convey the major storm flow, that is, the rainfall runoff resulting from the subject site and any external tributary areas using the Regulatory Storm without causing flood damage to proposed and adjacent public and private properties.

The City of Pickering's requirements for major system flow paths are as follows:

a) Overland flow shall be accommodated in road cross-sections and/or blocks of land dedicated to the municipality. The extent and top elevations of the major system flow path are to be shown on the grading plan drawings with a maximum flooding depth of 300 mm. Complete design calculations shall be prepared and submitted for approval.

b) Provide a minimum of 300 mm of freeboard between the maximum elevation of the major system flow path and the minimum entrance elevation (i.e., window well, garage, door, etc.), of any structure.

c) Overland flow depths for roads shall be within the standards in Table 4.

d) If the public has access to the major system flow path the maximum flow depths and velocities must be within the safety standards inTable 5. Flow must be contained within the road right-of-way (ROW).

e) Major system flow routes must be unobstructed with continuous slopes leading to SWM facilities, outlet structure or receiving watercourse. There shall not be any sags or low points on the major system flow path.

f) Where the major system from City of Pickering roads is connected to Region of Durham roads, the Region of Durham must be consulted and their criteria will need to be incorporated into the design.

g) In areas where major storm drainage capture is required, the major storm drainage must be captured and conveyed via storm sewer. The receiving storm sewer shall be sized to convey the 100 year event and dual drainage system analysis shall be completed in accordance with modelling requirements outlined in Section 6.3.

Table 4 - Major System Criteria

Type of Road	Major Storm	Criteria to Follow
Open Spaces	Greater than 5 year and up to the Regulatory Storm	As required for overland flow outlets
Local	Greater than 5 year and up to the Regulatory Storm	Maximum depth of flow shall be the lesser of 150 mm above the crown of the road or the water level up to the right-of-way.
Collector	Greater than 5 year and up to the Regulatory Storm	No barrier curb overtopping[1] Flow spread must leave at least one lane free of water.
Arterial	Greater than 10 year and up to the Regulatory Storm	No barrier curb overtopping[1] Flow spread must leave at least one lane free of water in each direction.
Road Underpass	Greater than 10 or 25 year and up to the Regulatory Storm	No barrier curb overtopping[1] Flow spread must leave at least one lane free of water in each direction.[2]

[1] When no barrier curb exists, encroachment onto adjacent private property is prohibited.

[2] For road underpasses with high traffic volumes and/or on a case-by-case basis alternate means such as pumping may be considered to increase the storm level of protection beyond the minor system capacity.

Table 5 - Permissible Depths and Velocities for Major System Flow Paths

Water Velocity (m/s)	Permissible Depth (m)
0.5	0.80
1.0	0.32
2.0	0.21
3.0	0.09

Major System Outlet Erosion Protection

Overland flow routes discharging to watercourses shall be designed to ensure the long-term stability of the overland flow path and to prevent erosion to the receiving system. They shall be designed to convey the uncontrolled Regulatory storm flow, defined as the larger of the 100 year or Regional storm flow, to the watercourse. Prior to entering the receiving system the overland flow route should incorporate measures to dissipate energy. To the greatest extent possible they shall be blended into the natural surroundings, in an aesthetically pleasing manner. Exit velocities shall not impart additional erosion potential to the streambed and banks. Major systems shall not outlet at the top of valley walls.

The proponent should position the outlet to minimize the angle at which the overland flow route ties into the creek. Overland flow routes to regulated watercourses require a permit from the Conservation Authority. The design of the overland flow route is to be submitted to the City as part of the full engineering submission.

3.2.1 Roadway Crossings

The minimum hydraulic capacity of culverts and bridges is summarized in the table below.

Table 6 - Roadway Crossing Hydraulic Requirements

Road Classification[1]	Design Capacity Return Frequency (Years)	
	Bridge and Culverts Total Span[2]	
	Less than 6.0 m	Greater than 6.0 m
Freeway Urban Arterial	50	100
Rural Arterial Collector	50	50
Local	50	50
Rural Local	25	25
Temporary Detour	1 to 5 Year	1 to 10 Year

[1] Road Classifications are defined as follows:
Freeway – a fully controlled access road exclusively for through traffic
Arterial Road – a road primarily for through traffic
Collector Road – a road on which traffic movement and access to property have similar importance
Local Road – a road primarily for access to property

[2] For purposes of selecting design flood criteria, total span is defined as the sum of the individual clear spans or diameters, measured parallel to the centerline of roadway in case of a bridge, and perpendicular to the longitudinal axis in the case of a culvert.

Notwithstanding MTO's drainage policy and guidelines, it is required that new roadway culverts and bridges have sufficient capacity to pass the Regulatory Flood in order to avoid adverse backwater effects.

Allowable Regulatory storm flood depths and velocities on roadways should be determined based on the standards within the current version of the Ontario Ministry of Natural Resources and Forestry (MNRF) Natural Hazards Technical Guidelines.

4.0 Stormwater Management Criteria

4.1 Water Quantity Control Criteria

All developing or re-developing areas must assess their potential impacts on local and regional flooding and mitigate to prevent impacts.

In areas without watershed water quantity control criteria it is the policy of the City to require that post-development peak flows are controlled to pre-development levels for the 2 year through 100 year events. Where watershed water quantity control criteria exist the proposed development will be required to comply with their recommendations.

All design submissions shall contain a statement from the designer indicating which SWM facilities have been reviewed and utilized in the design of the SWM system for the proposed development.

Any design of stormwater infrastructure involving the determination of peak flows or runoff volume must be supported with acceptable hydrologic calculations using rainfall information from the City. The following criteria apply:

- Only hydrologic models currently approved by the Ontario Ministry of Natural Resources and Forestry and/or the local Conservation Authority (CA) will be considered acceptable.
- Consideration will be given to the type of design methodology utilized depending upon the size and type of the site. Approved computer models are preferred.
- The City's IDF information and design storms are to be used (Table 12).
- Stormwater conveyance systems to be designed by completing a Dual Drainage analysis.
- All designs and calculations to be stamped and signed by a Professional Engineer licensed to practice in the Province of Ontario with education and experience in the field of Water Resources Engineering as per the Professional Engineer's Code of Ethics.

4.2 In-Stream Erosion Control Criteria

All developing or re-developing areas must assess their potential impacts on in-stream erosion and mitigate accordingly.

For greenfield development sites a detailed erosion control analysis based on a geomorphic assessment to determine critical erosion flow thresholds shall be completed. The erosion analysis shall be completed using a continuous hydrology model with a specified precipitation data set as per TRCA requirements. This is typically completed at the MESP and NFSSR stage. Details regarding the approved methodology may be obtained from the TRCA.

All development in areas with subwatershed erosion control criteria must conform with the targets developed in the respective MESP and NFSSR. For small infill sites and site plans less than 5 hectares the minimum erosion control requirements are:

- extended detention of the 4 hour, 25 mm Chicago distribution rainfall event for a minimum of 24 hours, or
- runoff reduction from the site through infiltration, evapotranspiration and reuse of a minimum 5mm of rainfall depth across all impervious surfaces.

4.3 Water Quality Control Criteria

All development must provide water quality control measures designed to provide Enhanced (Level 1) water quality control as defined by the MOE Design Manual.

Water quality treatment will be required for all new development within the City. Water quality treatment shall conform with the Ministry of the Environment, Conservation and Parks (MECP) requirements and shall use the treatment train approach to stormwater management with source, conveyance and end-of-pipe measures.

As a general consideration, maintenance of the natural water balance is encouraged where soil conditions permit. Reducing the volume of runoff has inherent water quality benefits as reducing the volume of runoff from a site will also reduce the loading of pollutants to watercourses. Therefore, the use of SWM facilities which reduce runoff volumes should be considered for each development.

Due to the presence of Red Side Dace in streams in Pickering, Owners should consult with the TRCA and MNRF early in the process to determine the requirements for conforming with the *Endangered Species Act*.

5.0 Stormwater Management Design Guidelines

The City of Pickering advocates the treatment train approach to SWM. SWM facilities are grouped under the following headings in order of preferred applications:

1. Source Control
2. Conveyance Control
3. End-of-Pipe Control

The design of source, conveyance and end-of-pipe controls shall be in accordance with guidance from the latest version of the MOE SWM Manual, the TRCA's Low Impact Development Stormwater Management Planning and Design Guide (LID Manual) in addition to relevant City policies.

5.1 Source Controls

5.1.1 Reduced Lot Grading

The City of Pickering does not endorse reduced lot grading.

5.1.2 Roof Leader Discharge to Surface

All lots with frontage 12.0 metres or less must have their downspouts connected to the storm sewer or a third pipe system discharging to an LID unless otherwise directed by the Director, Engineering Services Department.

For lots with frontage greater than 12.0 metres, roof leader discharge to surface is encouraged within the City of Pickering. Roof leaders should be directed to front or rear yard pervious (grassed) areas wherever possible to promote infiltration and shall not discharge to impervious areas directly connected to the storm sewer (e.g., sidewalks, driveways, parking areas). Roof leaders shall discharge to the ground surface via splash pads or extension pipes and flows shall be directed a minimum of 600 mm away from buildings to prevent ponding or seepage into the foundation drain. Roof leader outlet locations shall be identified on the lot development plan.

Where re-development is proposed, and where roof leaders within the existing development are currently directly connected to the storm sewer, the roof leaders within the re-developed area should be disconnected.

5.1.3 Roof Leader Discharge to Soakaway Pits

The City encourages soakaway pits provided they are in private ownership. An overflow connection to the storm sewer should be provided for lots with frontage 12.0 metres or less to ensure that in the event of the system failing that adequate drainage is maintained.

A soakaway pit is typically connected to the roof leader of a single house and may be used to store runoff and promote infiltration (subject to acceptable geotechnical and hydrogeological investigations in support of the approach). The maximum draw down time should be less than 72 hours, soils permitting. Longer drawdown times may be permitted where soils exhibit lower percolation rates.

Soakaway pits shall be located a minimum of 5.0 m from buildings with basements to avoid infiltration to drainage tiles and sump pumps and an overflow shall be provided.

5.1.4 Rear Lot Ponding

Rear lot ponding or other areas of extended ponding on residential lots is not permitted.

5.1.5 Greenroofs

The City encourages greenroofs and, in consultation with TRCA and MECP, will consider providing credit for them in terms of the water quality component of the SWM facilities. Where a credit has been given for the greenroof the Development Proponent will need to have it included in the site plan or plan of subdivision agreement, which shall remain on title.

Refer to the LID Manual for greenroof design guidelines.

5.1.6 Rooftop Storage

The City of Pickering does not allow rooftop storage for water quantity control due to the lack of municipal control over the practice.

5.1.7 Surface Storage

Commercial, industrial, institutional and infill residential developments have used parking lot and/or above ground storage to control post-development flows to the receiving storm sewer systems. In the case of infill residential developments, above ground storage is discouraged and the City’s preference is for underground storage.

The maximum ponding depth shall be 300 mm and grading shall be between 0.5% and 5%. The connection from the site into the receiving storm sewer system shall be through an orifice tube which restricts the flow to the required rate. The 5 year and 100 year ponding elevations and storage volume at each ponding location must be included on the design drawings. Ponding areas should be designed to ensure that they have a safe emergency overflow which directs water away from structures.

All surface storage designs shall be completed in accordance with the design guidance in the MOE SWM Manual and shall be included in the site plan or plan of subdivision agreement, which shall remain on title.

5.1.8 Detention Vaults

Detention vaults are usually precast concrete tanks constructed below grade which detain stormwater and release it at a controlled rate. The City of Pickering may permit the use of detention vaults to provide quantity control only for re-development sites, small sites or those designated in an MESP or NFSSR where no practical alternative exists for an end-of-pipe facility. The detention vault shall be included in the site plan or plan of subdivision agreement, which shall remain on title. The storm sewer connection from the detention vault into the receiving municipal sewer is to be controlled by an orifice pipe designed to restrict the inflow to the required rate. Metering chamber may be required to measure flows to the municipal system.

These systems may also incorporate an infiltration component where hydrogeological and geotechnical investigations support this approach. If the underground storage facility is designed for infiltration of road or parking lot runoff, a pretreatment structure, such as oil/grit separator or filter unit, shall be provided. The outlet structure shall be designed to meet the SWM control requirements. Any such facilities shall be readily accessible for any required maintenance activities.

5.1.9 Porous and Pervious Pavement

The City encourages porous and pervious pavement installations provided that they are not receiving runoff from high traffic areas where large amounts of de-icing salts are used or from source areas where land uses or activities have the potential to generate highly contaminated runoff (e.g., vehicle refueling, handling areas for hazardous materials). The design of these systems shall be in accordance with the guidance in the MOE SWM Manual and LID Manual.

5.1.10 Bioretention

Bioretention areas are designed to store and infiltrate stormwater runoff. Water quality is improved through the use of bioretention, as particles are filtered out as water passes through the filter bed. If the underlying soil has a low infiltration rate, an underdrain may be required to prevent standing water. The design of these systems shall be in accordance with the guidance in the MOE SWM Manual and LID Manual.

5.1.11 Soil Amendments

Soil amendments are used to improve the quality of existing soils, where compaction and a reduction in available organic material have degraded the soil. Improvements in the soil through the addition of compost and organic material will result in increased infiltration for LID practices, reduction in runoff volumes, and increased plant survival and growth. The design of these systems shall be in accordance with the guidance in the MOE SWM Manual and LID Manual. The City will not permit an allowance in the design of quality/erosion and quantity controls for soil amendments.

5.2 Conveyance Controls

5.2.1 Oversized (Super) Pipes

Oversized pipes are designed like storm sewers. Oversized pipes serve as both detention and conveyance structures. The City of Pickering may permit the use of oversized pipes to provide quantity control only for re-development, infill areas, and some smaller developments where geotechnical and hydrogeological investigations support this approach and where no practical alternative exists for an end-of-pipe facility. The design shall be in accordance with the guidance in the MOE SWM Manual. The storm sewer connection from the site into the receiving municipal sewer is to be controlled by an orifice pipe designed to restrict the inflow to the required rate.

Oversized pipes offer a feasible alternative to detention basins when a site has limited space; however, oversized pipes do not provide volume control or water quality benefits.

5.2.2 Pervious Pipe Systems

The City of Pickering encourages pervious pipe systems for stormwater from “clean” sources such as rooftops. Measures to prevent sediment and debris from entering these systems should be provided. Pervious pipe systems shall not be located within municipal right-of-way and shall be designed in accordance with the most current MOE SWM Manual and LID Manual and should always have an overflow mechanism into the storm sewer.

Subject to the City’s review, perforated pipe and catchbasin systems may be used to store stormwater and promote infiltration for treated runoff only (subject to acceptable geotechnical and hydrogeological investigations in support of the approach). Where perforated pipe systems are in private ownership they will be included in the site plan or plan of subdivision agreement.

5.2.3 Bioswales and Enhanced Grassed Swales

The City supports the use of bioswales and enhanced grassed swales. The design of these systems should be in accordance with the guidance from the MOE SWM Manual and the LID Manual.

5.3 End-of-Pipe Controls

All End-of-Pipe controls require access road designed as per requirements outlined in Section 5.4.9.

5.3.1 Infiltration Trenches

Infiltration trenches are permitted and encouraged for use in the City to promote infiltration of runoff (subject to acceptable geotechnical and hydrogeological investigations in support of the approach). Infiltration trenches shall not be located within proposed (fill) slopes or adjacent to significant valley land slopes. Measures to prevent sediment and debris from entering these systems should be provided. The maximum draw down time should be less than 72 hours, soils permitting. Longer drawdown times may be permitted where soils exhibit lower percolation rates provided that it has been accounted for in the design. Infiltration trenches shall be located a minimum of 5.0 metres from buildings with basements to avoid infiltration to drainage tiles and sump pumps and an overflow shall be provided. Bottom elevation of infiltration trench shall be a minimum of 1.0 metre above seasonal high ground water table. Refer to the MOE SWM Manual and LID Manual for infiltration trench design guidelines.

5.3.2 Sand Filters

Sand filters shall be limited to a drainage area less than 5 ha. Sand filters shall require a form of pre-treatment and shall not be used as a stand-alone SWM facility. The design should incorporate measures to allow the filter to be backwashed. The MOE SWM Manual outlines the conditions and criteria for filters.

5.3.3 Vegetated Filter Strips

Vegetated filter strips are vegetated areas adjacent impervious areas that improve the quality of and reduce the velocity of stormwater with gradual slopes and vegetation such as grasses. They are frequently used to pre-treat stormwater runoff prior to other LID practices such as infiltration trenches. Refer to the LID Manual for vegetated filter strip design guidelines.

5.3.4 Oil/Grit Separators

Subject to approval by the City and governing Conservation Authority, designated approved oil/grit separators may be installed on small sites less than 2 ha where a water quality control pond/wetland is not feasible. For developments on sites greater than 2 ha, oil/grit separators are only permitted as a pre-treatment in the treatment train approach in conjunction with other stormwater management options approved by the City.

Oil/grit separator devices must have current Canadian Environmental Technology Verification (ETV) or ISO 14034 ETV Verification. Oil/grit separator devices that were not tested for oil/fuel retention according to the provisions for the “Light Liquid Re-entrainment Simulation Test” specified under Section 5.0 in the Procedure for Laboratory Testing of Oil-Grit Separators, or which do not report the results of such testing in the ETV verification, are not permitted for installation in site applications that require oil or fuel capture. Oil/fuel spill hotspots include:

- Fueling stations
- Convenience stores
- Fast food restaurants
- High accident frequency traffic areas

When completing sizing calculations for oil/grit separators, the following guidelines shall apply:

- The approved TSS removal efficiency for oil/grit separator devices is 50% removal of the ETV particle size distribution.
- Oil/grit separator devices must be sized to capture and treat at least 90% of the runoff volume.
- Calculations shall be completed using the approved rainfall data for the City of Pickering (IDF data for Pickering) with a time interval of 15 minutes.
- Additional measures and supporting calculations shall be provided to demonstrate that the Enhanced Level of quality control treatment is achieved.

The oil/grit separator specified by the Engineer of Record in the stormwater management report and on approved site plan drawings cannot be substituted for a different model. The oil/grit separator shall be included in the site plan or plan of subdivision agreement, which shall remain on title. The owner is responsible for maintaining and repairing oil/grit separators installed on private property. Post-construction inspection of oil/grit separator devices is required to ensure that the device has been properly installed and is free of construction sediment and debris prior to commissioning. Operation and maintenance requirements for oil/grit separators shall be identified in the SWM report for the site and shall be implemented by the owner to ensure that the continued performance of the device as designed is achieved as per the Environmental Compliance Approval, if applicable. The Global Positioning System coordinates for oil/grit separator devices shall be provided on site servicing plans.

5.3.5 Extended Detention Wet Ponds

Wet ponds shall be designed in accordance with the governing guidelines which are currently documented in the MOE SWM Manual unless otherwise specified in the City's guidelines provided in Section 5.4.

5.3.6 Dry Ponds

Dry ponds shall not be permitted as a stand-alone treatment system. Dry ponds may be used as a part of a treatment train approach provided that the Enhanced level of water quality treatment is achieved. The City of Pickering encourages co-location of dry ponds within parks to provide water quantity storage.

5.3.7 Infiltration Basins

Infiltration basins shall not be accepted as a stand-alone end-of-pipe facility but may be considered as part of the treatment train and should be designed in accordance with the MOE SWM Manual.

5.4 Stormwater Management Facilities (Wet Ponds and Wetlands)

All new SWM facilities shall be designed to meet the Enhanced (Level 1) level of protection per the MOE SWM Manual as a minimum requirement unless otherwise specified in this document. An Operation and Maintenance Manual for the SWM facility (see Section 8.6 regarding reporting requirements) shall be submitted to the City for the site and shall be implemented by the owner to ensure that the continued performance of the facility as designed is achieved.

5.4.1 General Siting Guidelines

Generally, a SWM facility will need to be located near the lowest point of the site, so that it will be possible to convey both the major and minor system flow to the facility from the entire site. In certain circumstances, due to site topography, it may not be possible for all site drainage to be conveyed through the SWM facility before leaving the site. In these cases it may be necessary to provide additional SWM facility storage so that the post-development flows are equal to pre development (i.e., provide overcontrol).

SWM facilities should not be located adjacent to elementary schools, walkway routes leading to elementary schools or other active recreation areas frequented by young children.

5.4.2 Length-to-Width Ratio

The length-to-width ratio of a SWM facility is extremely important for the SWM facility's removal efficiency. The minimum length-to-width ratio shall be 4:1. Baffles and berms should be used to maximize the length-to-width ratio.

5.4.3 Grading (Side slope) and Retaining Walls

Grading within SWM facilities shall be designed in accordance with City of Pickering Standard P-1002. The maximum slope requirements for the various components of the facility are as follows:

- 3:1 (H:V) from the bottom of the permanent pool to 500 mm below the normal water level (NWL)
- 6:1 within 3.0 m on either side of the NWL
- 4:1 where the slope backs on to the rear yard lot line or an adjacent valley system
- 4:1 where the SWM facility is adjacent to a municipal boundary
- 5:1 where the slope backs on to an adjacent road system
- 5:1 where the SWM facility is being used as part of a trail system or passive recreation area

Retaining walls are not permitted within SWM facilities or within the ROW adjacent to SWM facilities.

5.4.4 Water Levels

Water levels within SWM facilities shall be designed in accordance with City of Pickering Standard P-1002.

Table 7 – Wet Pond and Wetland Depth Requirements

Component	Wet Pond Facility	Wetland Facility
Permanent Pool	1.0 to 2.0 m	0.15 to 0.30 m (75% of surface area) 1.0 m max for deep pools
Permanent Pool at Outlet	2.5 m max	2.0 m max
Extended Detention Storage	1.5 m max	1.0 m max < 10 year event
Quantity Control Storage	2.0 m max	2.0 m max
Overall Max Depth	4.5 m	4.0 m < 10 year event

Quantity control storage is to be provided in addition to requirements for extended detention (i.e., the quantity control storage is stacked on top of the extended detention storage).

Regarding hybrid wet pond/wetland facilities, the active storage depths for wetlands shall apply for the entire facility, unless a terraced, overflow configuration is employed.

A permanent marker/monument (e.g., pole or marked permanent landscape feature) shall be included in the design of the SWM facility to identify the elevation of the permanent pool, extended detention and 100 year water levels for visual verification of facility water elevations by operations staff.

5.4.5 Permanent Pool, Quality and Quantity Storage Requirements

The SWM facility sizing, including the permanent pool volume, quality and quantity volume shall be designed in accordance with the governing guidelines which are currently documented in the MOE SWM Manual.

For greenfield development sites a detailed erosion control analysis based on a geomorphic assessment of the receiving system to determine critical erosion flow thresholds shall be completed, which may become the determining factor for facility design and sizing. The erosion analysis shall be completed using a continuous hydrology model with a specified precipitation data set as per TRCA requirements. Details regarding the approved methodology may be obtained from the TRCA.

For small infill sites the minimum erosion control volume shall consist of the 25 mm 4 hour Chicago storm runoff volume released over 24 hours. The measurement of the detention time is between the centroids (i.e., the time corresponding to 50% of the volume of the hydrograph) of the SWM facility's inflow and outflow hydrographs.

5.4.6 Forebay

The forebay, including dispersion length, minimum required bottom width and forebay berm, shall be designed in accordance with the governing guidelines which are currently documented in the MOE SWM Manual.

A berm shall be constructed with a forebay spillway/weir invert elevation of 200 mm below the NWL with appropriate erosion protection to enable, at a minimum, the flow of the water quality event (25 mm, 4 hour event using the Chicago distribution) without overtopping any other part of the forebay into the main cell of the facility. The minimum top width of the berm shall be 1.0 m.

A de-watering sump per City of Pickering Standard P-1003 shall be installed in the forebay to enable the drawdown of the permanent pool for maintenance and sediment removal. Where feasible, the forebay sump shall be connected to the pond outlet structure with a control valve to drain by gravity. Where draining by gravity is not feasible, a dewatering sump shall be included and drained by pump.

Access road as per design requirements outlined in Section 5.4.9 shall be provided to the forebay.

The bottom of the forebay shall be lined with a maximum of 300 mm of 50 mm diameter crusher run limestone, or as recommended by a geotechnical engineer, to enable the use of maintenance equipment during sediment removal. Unstable native soils may warrant the use of geotextile lining under the limestone.

5.4.7 Berming

Berms around wetlands and wet ponds shall be designed with a minimum top width of 2.0 m (where trails and access roads are not located) with a 3:1 maximum side slope on the outside. The core of the berms shall be constructed with engineered fill on the basis of the recommendations of a licensed geotechnical engineer. Topsoil is not permitted for berm construction except as a dressing to support vegetation on the top of the core.

For pond berms exceeding 2.0 m in height, the berm must be designed by a geotechnical engineer with experience in the design of dams. Under no circumstances will the City approve berm heights in excess of 3.0 m. The berm's design must be in accordance with the requirements of the Ontario Dam Safety Guidelines (MNR, 1999) and the Lakes and River Improvement Act Technical Bulletins (MNRF, 2011) in addition to best practices for the design of dams. Furthermore, the construction of the berm must be supervised and certified by a geotechnical engineer with expertise in dams.

Due to the difficulty of achieving adequate compaction around pipes, and the potential for the pipe to become a preferential flow path for internal erosion in the embankment, known as piping, great care should be taken in the design of pipes through embankments. The length of pipe through the embankment should be minimized to the greatest degree possible and engineering designs will need to select the appropriate pipe material and bedding, determine if the pipe needs to be encased in concrete, minimize the number of pipe joints to ensure water tightness, design filters and/or anti-seepage collars.

The load cases and acceptable factors of safety listed below must be checked for embankments during the design process.

Table 8 - Load Cases and Factors of Safety

Load Case	Description	Minimum Factor of Safety
1	Upstream slope failure at the permanent pool	1.5
2	Upstream slope failure at the 100 year flood elevation	1.3
3	Upstream slope failure during rapid drawdown	1.25
4	Downstream slope failure at the permanent pool	1.5
5	Downstream slope failure at the 100 year flood elevation	1.3

Berms exceeding 2.0 m in height must have a liner for the seepage control. The liner must be designed by a geotechnical engineer and must be installed up to a maximum water surface elevation in the facility (100 year elevation).

The following resources provide comprehensive guidance for the design of dams and conduits through embankments:

- Ontario Dam Safety Guidelines (MNR, 1999)
- Lakes and River Improvement Act Technical Bulletins (MNRF, 2011)
- Design of Small Dams (USBR, 1987)
- Technical Manual: Conduits through Embankment Dams (FEMA, 2005)

5.4.8 Sediment Drying Area

A sediment drying area shall be provided immediately adjacent to the maintenance access road and to the sediment forebay to facilitate ease of access for sediment removal from the forebay and sediment storage.

A sediment drying area shall be provided as follows:

- sized for a minimum of 10 years of sediment accumulation
- sized assuming a maximum sediment height of 1.5 m and sediment slope of 10:1
- located at or above the predicted 2 year water level and near the maintenance access road
- setback a minimum of 6.0 m away from all property lines

Temporary sediment drying areas may be provided in adjacent parks and within road allowances with drainage directed back to the facility subject to approval by the City.

5.4.9 Maintenance Access Roadway

Maintenance access roads are required to all inlets, outlet structures, spillways, sediment forebays, sediment drying areas (if applicable) and outfall channels associated with SWM facilities. Access roads for emergency spillway outfall channels shall be incorporated into the design of the spillway where feasible (i.e., the access road is the outfall channel from the emergency spillway).

Where feasible, two access points shall be provided from the municipal road allowance such that the access road is looped to key hydraulic features. In situations where this is not practical, dead end access roads shall be designed with a hammerhead turning area consisting of a minimum hammerhead width of 17.0 m and a 12.0 m centreline turning radius.

The maintenance access road shall be designed as per City of Pickering Standard Drawings P-1007 to P-1010 or as recommended by a geotechnical engineer, if required. The access roads shall provide for all-weather ingress and egress with a minimum width of 4.0 m and a maximum grade of 10%. Curves on all access roads shall have a maximum centerline radius of 12.0 m. Bollards shall be designed as per City of Pickering Standard Drawing P-1006 and installed on the maintenance access road at all entrances. Where the access road enters the forebay, the forebay ramp shall be constructed of a cellular confinement system as per City of Pickering Standard Drawing P-1010 from 250 mm above the NWL to the forebay bottom.

5.4.10 Fencing

Fencing shall be installed around the perimeter of all SWM facilities to the satisfaction of the City. Due to the site specifics, the location shall be discussed with the City, who will provide final approval. Fencing shall not be permitted within berms.

Fencing shall be:

- 1.8 m high
- Secure
- Anti-climb
- Anti-cut
- Vandal-proof
- Highly transparent
- Attractive
- Durable

Maintenance access gates shall be a minimum 5m wide hinged single or double gates and installed at all entrances.

Shop drawings shall be provided to the City for final approval and included on the engineering drawings.

Special consideration shall be given where fencing is installed along overland flow routes and emergency spillways to ensure that the hydraulics are not effected due to debris accumulation and blockage. Modified details may be required through these sections of fencing.

5.4.11 Aesthetics

The SWM facilities shall be constructed with acceptable building materials (e.g., no gabions) to ensure that the facility is an aesthetically pleasing component of the community. A landscape plan shall be prepared as per the TRCA's Stormwater Management Pond Planting Guidelines. SWM facilities shall be integrated with parks and trails where feasible.

5.4.12 Warning Signage

Warning signs shall be clearly visible and erected at all access points to the SWM facility. Warning signs shall be supplied and installed by the developer and designed in accordance with City of Pickering Standard P-1005.

5.4.13 Inlet Structures

Inlet structures shall be installed with the invert set to the NWL or higher. Submerged inlets shall only be permitted if the obvert of the pipe lies below the maximum anticipated thickness of ice.

Suitable erosion control and energy dissipation treatment shall be provided at all inlets to the SWM facility. The sizing of rip rap or river stone shall be based on appropriate erosive velocity calculations. Maintenance access roads shall be provided to all inlet structures as per Section 5.4.9.

Headwalls and safety grating shall be installed at all inlets as per City of Pickering Engineering Services Standards P-300 (headwall) and P-304 (inlet headwall grating). SWM facility inlet elevations are to be designed such that the 1 in 5 year storm design sewer capacity as per the storm sewer design sheet is maintained and not reduced due to tailwater conditions.

5.4.14 Outlet Control Structures

Outlet control structures shall be designed with flow regulating devices (e.g., orifice) to control the flow and facility drawdown time. Wet pond outlet structures shall be designed with a reverse slope bottom draw pipe as per City of Pickering Standards P-1000 and P-1001, respectively.

Outlet structures are to be designed in a safe and aesthetically pleasing manner with the majority of the structure contained within the berm. A bottom draw pipe should be installed at the intake connected to the outlet control structure. A maintenance drawdown pipe with valve as per City of Pickering Standard Drawing P-1011 shall be installed where feasible to enable the dewatering of the pond by gravity for maintenance activities such as sediment removal.

Suitable erosion control and energy dissipation treatment shall be provided at the facility outfall per City of Pickering Standard P-1004 where it discharges to the receiving body. The sizing of rip rap or river stone at the outfall shall be based on appropriate erosive velocity calculations. Maintenance access roads shall be provided to all outlet structures as per Section 5.4.9.

The outlet structure should be designed to operate under free-flowing conditions where feasible. The return period water surface elevations of the receiving body must be determined and verified to ensure the proper operation of the outlet structure. Where it is not feasible to operate the outlet structure under free-flowing conditions, appropriate submergence calculations must be completed to ensure that the outlet structure is sized correctly.

For SWM facilities located downstream of areas with a high susceptibility to the occurrence of spills, such as industrial areas, a shut-off valve on the outlet structure shall be provided.

The length of pipe through the embankments should be minimized to the greatest degree possible as they undermine the structural integrity of the embankment.

5.4.15 Emergency Spillway

All SWM facilities shall be designed with an emergency spillway consistent with City of Pickering Standard Drawings P-1000. The emergency spillway shall be designed to convey the larger of the uncontrolled 100 year or the uncontrolled Regional Storm peak flow with the invert of the spillway set, as a minimum, at the 100 year controlled water level. A freeboard of 300 mm shall be provided above the maximum water level of the uncontrolled 100 year or uncontrolled Regional storm flow, whichever is greater, on the emergency spillway to the top of the pond berm.

The spillway design shall incorporate erosion protection measures that are adequately sized to withstand the erosive forces associated with the uncontrolled Regulatory storm flow. The location of transitions from supercritical to subcritical flow regimes (i.e., hydraulic jumps) on the spillway and in the outfall channel shall be determined and erosion protection measures shall be designed accordingly. The erosion protection shall be integrated with a natural vegetated surface treatment that is aesthetically pleasing where feasible (e.g., cellular confinement system covered with topsoil and sod).

Spillway side slopes shall not be steeper than 3:1 and shall be no steeper than 10:1 when incorporated into the access road. The spillway shall not be located directly above the outlet control structure and a minimum clearance of 3.0 m shall be provided.

The emergency spillway shall have an outfall channel which safely conveys the uncontrolled Regulatory storm flow, defined as the larger of the 100 year or Regional storm, from the emergency spillway to the pond's main outfall channel or directly to the watercourse. Where feasible the outfall channel from the emergency spillway shall be designed as a maintenance access road (i.e., the outfall channel is also the access road) as per Section 5.4.9. The emergency spillway outfall channel shall conform with the requirements for outfall channels in 5.4.17.

5.4.16 Major System Overland Flow Routes

The major system overland flow route to the SWM facility shall be designed to safely convey the Regulatory storm's overland flow. Should the overland flow route to the SWM facility consist of the access road and path, then the flow depth shall not exceed 300 mm or a velocity of 0.65 m/s. Where feasible, the overland flow should not be directed into the forebay to avoid the re-suspension of settled sediments.

5.4.17 Outfall Channels

The outfall channel design shall incorporate erosion protection measures that are adequately sized to withstand the erosive forces associated with design peak flow for the 100 year event, from the SWM facility. Where emergency spillway incorporated into outfall channel, the uncontrolled peak flow for the Regulatory storm event, defined as the larger of the uncontrolled 100 year event or uncontrolled Regional Storm shall be used for the channel design. The design flow shall be contained within the banks of the engineered outfall channel. The location of transitions from supercritical to subcritical flow regimes (i.e., hydraulic jumps) in the outfall channel shall be determined and erosion protection measures shall be designed accordingly. The erosion protection shall be integrated with a natural vegetated surface treatment that is aesthetically pleasing where feasible (e.g., cellular confinement system filled with topsoil and seeded). Maintenance access roads shall be provided to all outfall channels as per Section 5.4.9.

5.4.18 Anti-seepage Collars

Anti-seepage collars shall be installed on all outlet pipes or as directed by a Geotechnical Engineer.

5.4.19 Existing Groundwater Elevation

The bottom of the SWM facility shall be a minimum of 1.0 m above the seasonal high GWL unless it can be demonstrated by a hydrogeologist to the satisfaction of the City that there will be no impact to groundwater elevation and groundwater quality. Otherwise, if it is not feasible to maintain the required separation distance, a suitable liner (e.g., clay or synthetic liner) shall be installed based on consultation with a geotechnical engineer. The seasonal high GWL shall be measured at forebay and main cells of SWM facility.

5.4.20 Liners

Liners shall be installed so that they can be covered with a maximum of 300 mm of top dressing which will act as a “reminder layer”. Top dressing shall consist of 150 mm of crushed rock covered with 150 mm of native soil. The rock layer is to mark the location of the liner for future maintenance operations. As an alternative to crushed rock, a minimum of 300 mm of native soil may be used if orange plastic “safety fencing” or another highly-visible, continuous marker is embedded 150 mm above the membrane. This will ensure that during maintenance operations machinery operators know when they have reached the bottom of the SWM facility and do not over excavate and damage the liner.

Clay Liners

- Liner thickness shall be specified by a Geotechnical Engineer.
- Clay shall be compacted to 95% minimum dry density, modified proctor method (ASTM D-1557).
- The slope of clay liners must be restricted to 3:1 for all areas requiring soil cover; otherwise, the soil layer must be stabilized by another method so that soil slippage into the facility does not occur. Any alternative soil stabilization method must take maintenance access into consideration.
- Where clay liners form the sides of ponds, the interior side slope should not be steeper than 3:1, irrespective of fencing. This restriction is to ensure that anyone falling into the pond may safely climb out.
- Where the pond is under uplift pressure from the groundwater table the liner must be designed to stay in place when the pond is emptied for maintenance operations.

Geomembrane/Geosynthetic Clay Liners

- Shall be ultraviolet (UV) light resistant and have a minimum thickness of 30 mils. A thickness of 40 mils shall be used in areas of maintenance access or where heavy machinery must be operated over the membrane.
- Shall be bedded according to the manufacturer's recommendations.
- If possible, liners should be of a contrasting color so that maintenance workers are aware of any areas where a liner may have become exposed when maintaining the facility.
- Shall not be used on slopes steeper than 5:1 to prevent the top dressing material from slipping. Textured liners may be used on slopes up to 3:1 upon recommendation by a geotechnical engineer that the top dressing will be stable for all site conditions, including maintenance.
- Where the pond is under uplift pressure from the groundwater table the liner must be designed to stay in place when the pond is emptied for maintenance operations.

5.4.21 Fire Use

In certain locations of the City (e.g., remote development locations where access to fire hydrants is not available), and subject to review by the City, it may be desirable to utilize the SWM pond as a source of water for fire use by incorporating a dry hydrant design. The design must meet the requirements of the Ontario Building Code for dry hydrants which is currently in accordance with FPA 1142, Water Supplies for Suburban and Rural Fire Fighting.

5.4.22 West Nile Virus

Reasonable measures should be incorporated in the design of wet ponds and wetlands to minimize the proliferation of mosquitoes and the potential spread of the West Nile virus and to reduce the need to apply larvicide. Such measures, which focus on creating habitat less suitable for mosquito breeding and survival, include the following (adapted from TRCA Innovative Stormwater Management Workshop, Culex Environmental, May 2008):

- Encourage a plant-dominated state as opposed to an algae-dominated state – A plant dominated state (i.e., lots of submerged and floating-leaved aquatic plants) provides habitat for predators whereas an algae dominated state is less favourable for predators and more favourable for mosquitoes with increased availability of nutrients and turbidity as a food source and warmer water. In addition, mosquito larvae tend to avoid submerged and floating-leaved plants.

- Introduce predators – Along with a plant-dominated state introduce predators that feed on mosquito eggs and larvae, such as: grazing invertebrates (e.g., snails, Mayfly larvae, Chironomids), neustonic insects (e.g., water striders, water boatmen, whirligig beetles), benthic invertebrates (e.g., flatworms, leeches, Asellus, shrimps), three-spined sticklebacks, fathead minnows, dragonfly nymphs, water beetles, Alderfly larvae, and frogs and toads. In addition, bird and bat houses should be erected to encourage the nesting of bats and birds such as swallows and purple martins which rely on flying insects including mosquitoes as their primary food source.

- Maximize water depths – where possible, the minimum depth of water within the permanent pool should be 1.0 m or greater.

5.4.23 Thermal Impacts

When discharging stormwater to a watercourse identified as a cold water fishery, mitigation measures such as shoreline planting, shading with trees, bottom draw outlet pipes from deeper pools, or cooling trenches shall be implemented in SWM facilities to minimize thermal loading to the receiving watercourse. Bottom draw quality control pipes should have an inlet invert 0.50 m above the bottom of the SWM facility to prevent sediment from entering the pipe. Cooling trenches should have a minimum length of 30 m.

5.4.24 Maintenance and Inspections Protocol

An Operation and Maintenance Manual shall be prepared that identifies ongoing operation protocol including inspection and maintenance issues. The reporting requirements for the Operation and Maintenance Manual are provided in Section 8.6.

5.4.25 Naturalized vs. Manicured SWM Facilities

The City requires the design of SWM facility using a naturalized landscape plan with native plant species. Naturalized SWM facilities are beneficial in that they require less maintenance and may provide more habitat for native flora and fauna than manicured facilities. Naturalization may also make the facility more aesthetically pleasing to local residents. Naturalized facilities should offer improvements in reducing stormwater runoff, improving TSS removal, and providing better shading of the pond to reduce the temperature of outflow. Manicured facilities require more frequent grass cutting and weed control which can lead to reduced water quality benefits. Manicured SWM facilities may be permitted under special circumstances where it can be demonstrated that a naturalized facility is grossly “out of character” with the surrounding architecture or in order to meet special operations needs.

5.4.26 Fountains and Bubblers

Due to concerns regarding maintenance and potential impacts to particle settling and re suspension of sediments, fountains and bubblers are not permitted in SWM facilities.

5.4.27 Stormwater Management Facility Planting Guidelines

The landscape design and planting requirements for SWM facilities shall be consistent with the current TRCA’s Stormwater Management Pond Planting Guidelines. A copy of the TRCA’s September 2007 planting guidelines is provided in the Engineering Services Design Standards under “1000 – Stormwater Management Design Details”.

5.4.28 Temporary and Interim Stormwater Management Facility

Temporary or interim SWM facilities proposed for Regional Roads or a new development shall not be constructed to ultimate design conditions. Temporary or interim SWM facilities are the responsibility of the owner. The City is not responsible for operation and maintenance of these facilities.

6.0 Guidelines for Hydrologic and Hydraulic Analysis

The analytical methods presented represent established techniques that are acceptable to the City of Pickering. The proponent is not limited to the methods herein. However, approval from the City of Pickering and review agencies is required prior to using alternative hydrologic and hydraulic analytical techniques.

6.1 Guidance on the Use of Computer Programs by Professional Engineers

All practitioners or proponents who plan to use computer models or programs in their designs shall familiarize themselves with the PEO Guideline for Professional Engineers Using Software-Based Engineering Tools (PEO, 2011). Excerpts from this guideline are included below:

- The practice of professional engineering has become increasingly reliant on computers, and engineers use many computer programs that incorporate engineering principles and matters. Many of these programs are based upon or include assumptions, limitations, interpretations and judgments on engineering matters that were made by or on behalf of an engineer when the program was first developed. Therefore, it is often difficult to determine, just by using a program or by being given a description of its function, the engineering principles and matters it incorporates.

- Professional engineers are responsible for all aspects of the design or analysis they incorporate into their work, whether it is done by an engineering intern, a technologist or a computer program. Therefore, practitioners are advised always to use the data obtained from engineering software judiciously and only after submitting results to a vigorous checking process to ensure the practitioner’s due diligence obligations are fulfilled.

- Due diligence is the effort expected to be made by an ordinarily prudent or reasonable party to avoid harm to another party. A practitioner’s due diligence is best demonstrated by taking an organized approach to ensuring all potential sources of error and omission are assessed and, if necessary, corrected before any action is taken.

- All practitioners must have an acceptable knowledge of and experience in the engineering principles involved in all the work they undertake. Article 72(2)(h), O. Reg. 941 under the *Professional Engineers Act* identifies one criterion of professional misconduct as “undertaking work the practitioner is not competent to perform by virtue of the practitioner’s training and experience”. Using software to automate part of the work does not relieve practitioners of the obligation to provide services only in their areas of competence.

- Engineering programs are based upon or include assumptions, limitations, interpretations and judgments on engineering matters that were made by or on behalf of the user when the program was first developed. It is often difficult to determine just by using a program or by being given a description of its function how the software deals with the engineering principles and technical information it incorporates.

- Engineers should become familiar with the engineering principles, equations, models, algorithms and assumptions used in the software. Some developers provide manuals, or white papers, containing detailed explanations of the software's underlying structure. Practitioners should acquire and review these documents.

- The engineer must have a suitable knowledge of the engineering principles involved in the work being conducted, and is responsible for the appropriate application of these principles. When using computer programs to assist in this work, engineers should be aware of the engineering principles and matters they include, and are responsible for the interpretation and correct application of the results provided by the programs.

6.2 Hydrology

6.2.1 Event Based Hydrologic Models

The Ontario Ministry of Natural Resources Floodplain Management in Ontario Technical Guidelines provide guidance on hydrologic models approved for use in Ontario.

Sound hydrologic modelling standards of practice should be followed in developing an event based hydrologic model. The following standards of practice are intended as a guide for hydrologic modelling:

1. The modeller should provide the purpose for developing the hydrologic model (e.g., determining flow rates, runoff volumes, etc.).

2. The modeller should provide the study objectives and how they relate to the hydrologic modelling.

3. The modeller should provide the model selection criteria and how the model matches the criteria.

4. The modeller should outline how the design storm has been selected.

5. The modeller should provide drainage area plans outlining both internal and external catchments, modelling schematics and tables providing drainage area parameters.

6. Background information on the drainage area parameters should be provided and all assumptions shall be appropriately justified.

7. Background data on major and minor systems should be provided with plans clearly presenting and labeling both systems.

8. Detailed plans and calculations should be provided outlining how the stage/discharge relationship for storage systems has been determined.

9. Sensitivity analysis should be completed on critical parameters to assess the model's uncertainty.

10. Verification or validation of results should be provided through various methods such as calibration to recorded stream flow, unit flow rates and runoff volume comparisons using the techniques such as the Regional Headwater Hydrology Study (RRHS, TRCA), MTO index method or equivalent. The application of the validation technique will depend on the availability of data and the sensitivity of the analysis.

11. The modeller should provide all input and output details in a logical manner. Any errors shall be appropriately explained.

6.2.2 Continuous Models

Continuous models are usually more complex than event based hydrologic models, as typically the models consider additional processes including temperature, evapotranspiration, snow conditions and groundwater. The standards of practice for Event Based models from the proceeding section also apply to Continuous Models. In the TRCA's jurisdiction Continuous models are typically used for determining erosion control targets.

6.2.3 Rational Method

Flows for sizing storm sewers shall be determined using the Rational Method and Pickering's IDF data (Table 12) for sewershed areas less than 40 hectares. For sewersheds larger than 40 hectares a dynamic computer model should be used. The Rational Method can be used more generally for estimating flows for drainage areas less than 5 hectares.

The assumptions in the Rational Method are as follows:

1. The drainage area should be smaller than 40 hectares.

2. The peak discharge occurs when the entire watershed is contributing flow.

3. A storm that has a duration equal to the time of concentration produces the highest peak discharge for this frequency.

4. The rainfall intensity is uniform over a storm time duration equal to the time of concentration. The time of concentration is the time required for water to travel from the hydrologically most remote point of the basin to the outlet or point of interest.

5. The frequency of the computed peak flow is equal to the frequency of the rainfall intensity. In other words, the 10 year rainfall intensity, *i*, is assumed to produce the 10 year peak discharge.

The design flow, in each length of sewer, shall be computed using the Rational Method and the City of Pickering's IDF curves, standard runoff coefficients and storm sewer design sheets according to the "Rational" formula:

$Q = 0.00278 A \times I \times C$ where:

Q = peak runoff rate (m^3/s)
A = contributing drainage area (ha)
I = rainfall intensity (mm/hr)
C = runoff co-efficient

Runoff Coefficient Adjustment for 25-100 Year Storms

The runoff coefficients (C) in Tables 9, 10 and 11 below are applicable for 2, 5 and 10 year storm frequencies. For less frequent storms an Antecedent Precipitation Factor (Ca) should be used and Rational formula to be modified accordingly to:

Q = 0.00278 A x I x Ca x C where:

'Ca' values are listed below:

1 to 10 year storm - Ca = 1.00
25 year storm - Ca = 1.10
50 year storm - Ca = 1.20
100 year storm - Ca = 1.25

and the product of 'Ca x C' should not exceed 1.00.

City Runoff Coefficients

Runoff coefficients to be used in storm sewer design shall be as follows:

Table 9 - Pickering Standard Runoff Coefficients by Land Use

Land Use	Run-off Coefficient
Parks over 4 hectares	0.20
Unimproved	0.20
Parks 4 hectares and under	0.25
Railroad Yard	0.35
Single Family Residential	0.65
Single Family Residential (Frontage less than 12.2m)	0.70
Semi-detached Residential	0.70
Street Townhouses	0.75
Laneway Townhouses	0.85
Back-to-Back Townhouses	0.90
Apartments	0.85
Schools and Churches	0.85
Industrial	0.90
Commercial	0.90
Heavily Developed Areas	0.95
Paved Areas	0.95

Table 10 - Pickering Standard Runoff Coefficients by Ground Cover and Slope

Character of Surface		Runoff Coefficient
Pavement – Asphalt and Concrete		0.95
Stone, brick and precast concrete paving panels	With Sealed Joints	0.95
	With Open Joints	0.65
Gravel Road and Shoulder		0.70
Roofs		0.95
Greenroofs		0.50[1]
Lawns – Sandy Soil	Flat, 0-2% Slope	0.05 – 0.10
	Average, 2-7% Slope	0.10 – 0.15
	Steep, > 7% Slope	0.15 – 0.20
Lawns – Heavy Soil	Flat, 0-2% Slope	0.13 – 0.17
	Average, 2-7% Slope	0.18 – 0.22
	Steep, > 7% Slope	0.25 – 0.35
Water Impoundment		1.00

[1] Only applies to the greenroof portion of the roof

Table 11 - Pickering Standard Runoff Coefficients for Pervious Areas

Vegetation	Topography	Soil Texture		
		Open Sandy Loam	Clay and Silt Loam	Tight Clay
Woodland	Flat, 0-5% Slope	0.10	0.30	0.40
	Rolling, 5-10% Slope	0.25	0.35	0.50
	Hilly, 10-30% Slope	0.30	0.50	0.60
Pasture	Flat	0.10	0.30	0.40
	Rolling	0.16	0.36	0.55
	Hilly	0.22	0.42	0.60
Cultivated	Flat	0.30	0.50	0.60
	Rolling	0.40	0.60	0.70
	Hilly	0.52	0.72	0.82

6.2.4 Rainfall

Intensity-Duration-Frequency (IDF)

The City of Pickering's IDF data (refer to Table 12) shall be used to determine the appropriate rainfall intensity for use with the Rational Method. The equations are also provided. IDF data has been revised from the previous City of Pickering standards.

The equation of IDF curves is expressed as:

$$I = \frac{A}{(t_c + B)^C}$$

where I = intensity of rainfall in mm/hour
t_c = time of concentration in minutes for the cumulative drainage area to the point of interest

Table 12 - Pickering IDF Parameters

Parameter	Return Period					
	2 Year	5 Year	10 Year	25 Year	50 Year	100 Year
A	715.076	1082.901	1313.979	1581.718	1828.009	2096.425
B	5.262	6.007	6.026	6.007	6.193	6.485
C	0.815	0.837	0.845	0.848	0.856	0.863

Temporal Distributions

The Atmospheric Environment Service (AES) storms shall be applied for determining water quantity control requirements. Both the AES 1 hour and 12 hour duration storms shall be applied to determine the critical storm for the design of SWM infrastructure for the 1 in 2 year through 1 in 100 year storm. The 25 mm 4-hour Chicago storm shall be applied to determine erosion control requirements where subwatershed specific erosion control criteria do not exist. The data for these storms is in Appendix A.

6.2.5 Time of Concentration

The time of concentration is the travel time of a wave from the most hydraulically remote point in the contributing area to the point of interest. It can be considered to be the sum of the of overland flow travel time and times of travel in street gutters, roadside swales, storm sewers, drainage channels, small streams and other conveyance systems (ASCE Code of Practice 77, 1993).

There is rarely streamflow data available for practitioners to use to derive an accurate representation of the catchment's time of concentration. In the absence of data, practitioners must exercise sound engineering judgment in the determination of this parameter as peak flow calculations are sensitive to the time of concentration.

Time of concentration varies with the size and shape of the drainage area, the land slope, the type of surface and land uses within the catchment, the intensity of rainfall, and whether flow is overland or channelized. Channelized flow is typically further divided into shallow concentrated flow and concentrated flow, resulting in the definition of three primary flow paths: overland, shallow concentrated and concentrated.

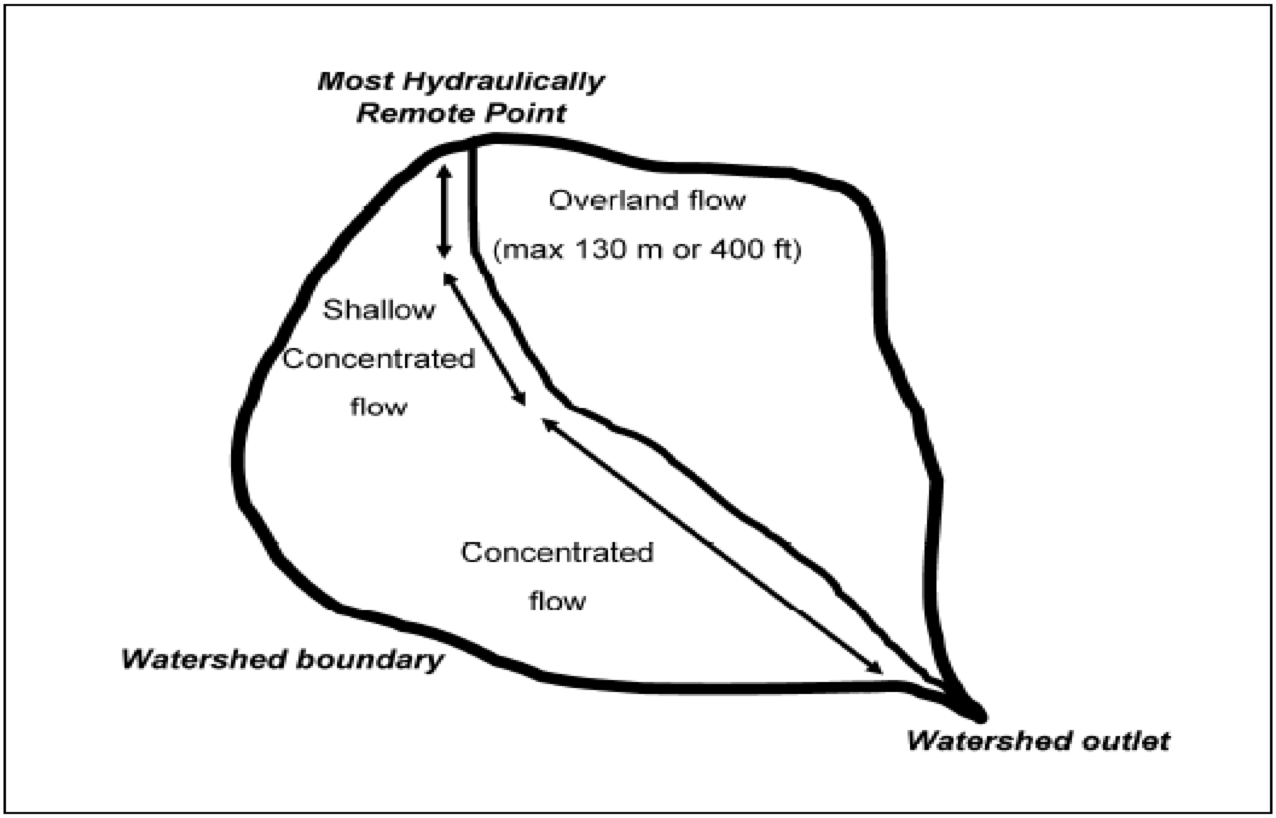


Figure 3 - Overland Flow Components

Overland flow occurs in the upper reaches of a watershed as shallow, sheet flow, typically at flow depths of 20 to 30 mm or less. Such flow occurs over short distances prior to the point where topography and surface characteristics cause the flow to concentrate in rills and small swales. Shallow concentrated flow occurs in rills and swales at depths on the order of 40 to 100 mm. As flow continues to accumulate concentrated flow occurs in larger and deeper amounts in typical open channel conveyances (gulleys, ditches, storm drains, etc.). Figure 3 illustrates a typical subdivision of these 3 different flow paths from the upper end of a watershed to the lower end. It is not always apparent when the flow changes from overland flow to shallow concentrated flow. If there is no field evidence of small channels or concentrated flow conditions, it is reasonable to assume a maximum overland flow length of 130 metres.

Given that calculated design flows are very sensitivity to the time of concentration parameter, care should be taken to use the most appropriate formula for each segment of the flow path in calculating the time of concentration for a catchment. Furthermore, for small catchments it is particularly important that the overland flow component of the time of concentration calculation is properly represented as calculations which assume that runoff at the head of the catchment is in a channel are incorrect and will lead to the time of concentration being underestimated. In all cases the practitioner is responsible for exercising sound engineering judgment to accurately represent the rainfall runoff processes in their analysis.

Factors Affecting Time of Concentration

Surface Roughness

One of the most significant effects of urban development on flow velocity is less retardance to flow. That is, undeveloped areas with very slow and shallow overland flow through vegetation become modified by urban development: the flow is then delivered to streets, gutters, and storm sewers that transport runoff downstream more rapidly. Travel time through the watershed is generally decreased.

Partial Area Effects

In general, the appropriate time of concentration for calculation of the flow at any point is the longest time of travel to that point. However, in some situations, the maximum flow may occur when only part of the upstream catchment is contributing. Thus the product of a lesser catchment area and a higher peak intensity from the IDF curve (resulting from a lower time of concentration) may produce a greater peak discharge than that if the whole upstream catchment is considered. This is known as the **"Partial Area Effect"**.

Usually the above effect results from the existence of a sub-catchment of relatively small catchment area but a considerably longer than average time of concentration. This can result from differences within a catchment of surface slope, or from catchment shape. Typical cases include a playing field or open space within a residential area, or an elongated catchment. Figure 4 shows various examples.

In urban catchments this applies, for example, where large paved areas are directly connected to the pipe inlet, and the subcatchment discharge is based on a larger pervious area. Similarly, partial area effects can also occur where a large open space catchment, contributes to an urban catchment, with a time of concentration substantially different to the urban catchment. Other factors of influence may be catchment shape, or variation in slope and land use within the catchment. In areas where this is critical, such as industrial or high density residential development, a partial area check, based on times of concentration of impervious areas directly connected to the pipe system, is necessary.

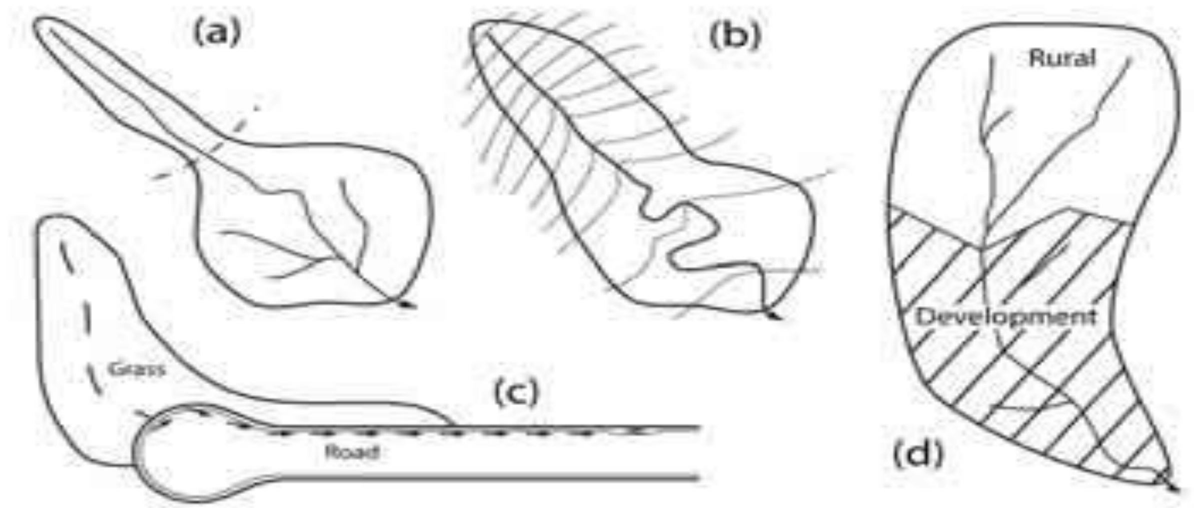


Figure 4 - Examples of catchments that may be subject to partial area effects (Queensland Urban Drainage Manual, 2007)

It is important to note that particular sub-catchments may not produce partial area effects when considered individually, but when combined at some downstream point with other sub-catchments, the peak discharge may result when only parts of these sub-catchments are contributing.

The onus is on the designer to be aware of the possibility of the "Partial Area Effect" and to check as necessary to ensure that an appropriate peak discharge is obtained. There are 2 generally accepted Rational Method-based procedures for the calculation of peak flow rates from partial areas as presented below; however, it is generally recommended that the hydrologic assessment of catchments with unusual or widely varying surface features should be undertaken with an appropriate numerical runoff-routing model.

Channel Shape and Flow Patterns

In small non-urban watersheds, much of the travel time results from overland flow in upstream areas. Typically, urbanization reduces overland flow lengths by conveying storm runoff into a channel as soon as possible. Since channel designs have efficient hydraulic characteristics, runoff flow velocity increases and travel time decreases.

Slope

Slopes may be increased or decreased by urbanization, depending on the extent of site grading or the extent to which storm sewers and street ditches are used in the design of the water management system. Slope will tend to increase when channels are straightened and decrease when overland flow is directed through storm sewers, street gutters, and diversions.

Time of Concentration Equations

The time of concentration for a catchment is the sum of the travel times of each flow segment:

Equation 1 - Time of Concentration Equation

$$t_c = \sum (t_{overland} + t_{shallow} + t_{concentrated})$$

Overland Flow

Overland flow or sheet flow is the shallow mass of runoff on a planar surface with a uniform depth across the sloping surface. This usually occurs at the headwater of streams over relatively short distances, rarely more than about 130 metres. The most accurate way to estimate the overland flow travel time is with a version of the kinematic wave equation, a derivative of Manning's equation, shown as:

Equation 2 - Kinematic Wave Equation

$$t_{ti} = \frac{0.438\ L^{0.6} n^{0.6}}{I^{0.4} S^{0.3}}$$

where t_{ti} = overland flow travel time (min)
L = overland flow length (m)
n = Manning’s roughness coefficient
I = rainfall rate (metres/hr)
S = average slope of the overland area

Table 13 - Manning's "n" Roughness Coefficients for Overland Flow

Surface Description	Manning's "n" Roughness Coefficient[1]
Smooth surfaces (concrete, asphalt, gravel or bare soil)	0.011
Fallow field (no residue)	0.05
Cultivated Soil – Residue Cover < 20%	0.06
Cultivated Soil – Residue Cover > 20%	0.17
Short Prairie Grass	0.15
Dense Grasses[2]	0.24
Bermudagrass	0.41
Woods – Light Underbrush[3]	0.40
Woods – Dense Underbrush[3]	0.80

[1] The n values are a composite of information compiled by Engman (1986).

[2] Includes species such as weeping lovegrass, bluegrass, buffalo grass, blue grama grass, and native grass mixtures.

[3] When selecting "n", consider cover to a height of about 5 cm. This is the only part of the plant cover that will obstruct sheet flow.

Shallow Concentrated Flow

After a maximum of 100 metres, sheet flow tends to concentrate in rills and then gullies of increasing proportions and is referred to as shallow concentrated flow. The velocity of such flow can be estimated using a relationship between velocity and slope from the equation:

Equation 3 - Shallow Concentrated Flow Equation

$$V = k\, S_p^{\;0.5}$$

where
- V = velocity (m/s)
- k = intercept coefficient
- S_p = slope (%)

Table 14 - Intercept Coefficient for Shallow Concentrated Flow Equation

Land Cover/Flow Regime	*k*
Forest with heavy ground litter; hay meadow (overland flow)	0.076
Trash fallow or minimum tillage cultivation; contour or strip cropped; woodland (overland flow)	0.152
Short grass pasture (overland flow)	0.213
Cultivated straight row (overland flow)	0.274
Nearly bare and untilled (overland flow); alluvial fans in western mountain regions	0.305
Grassed waterway (shallow concentrated flow)	0.457
Unpaved (shallow concentrated flow)	0.491
Paved area (shallow concentrated flow); small upland gullies	0.619

Tillage can affect the direction of shallow concentrated flow. Flow may not always be directly down the watershed slope if tillage runs across the slope which should be accounted for in the determination of the flow length. After determining the average velocity, use the equation below to estimate travel time for the shallow concentrated flow segment.

Equation 4 - Travel Time for Shallow Concentrated Flow

$$t_{ti} = \frac{L}{60V}$$

where
t_{ti} = travel time for segment i (min)
L = flow length for segment I (m)
V = velocity for segment i (m/s)

Channelized Flow

In concentrated flow conditions the velocity is typically estimated from the Manning's equation based on either full pipe conditions for storm drains or bankfull conditions for channel sections.

Equation 5 - Manning's Equation

$$V = \frac{1}{n} R^{\frac{2}{3}} S^{\frac{1}{2}}$$

where
V = velocity for segment i (m/s)
n = Manning's roughness coefficient
R = hydraulic radius (m)
S = slope (m/m)

Table 15 - Manning's Roughness Coefficients for Channelized Concentrated Flow

Location	Cover	Manning's "n"
Overbank	Woods	0.080 – 0.12
	Meadow	0.055 – 0.07
	Lawns	0.035 – 0.05
Channel	Natural	0.030 – 0.08
	Grass	0.030 – 0.05
	Natural Rock	0.030
	Armour Stone	0.025
	Concrete/Asphalt	0.015
	Articulated Block (e.g., Terrafix)	0.020
	Gabions	0.025
	Wood	0.015
	Corrugated Steel Pipe – 3" x 1"	0.024
	Structural Plate Corrugated Steel Pipe – 6" x 2"	0.032

6.2.6 Calculation of Model Parameters

Model parameters shall be site specific, area weighted if required, and provided with the design documents. Soils information shall be obtained from on-site soil testing (e.g., borehole data) or soil survey mapping (e.g., Soil Survey of Durham County).

Table 16 - Curve Numbers for Selected Land Uses

Land Use Description	Hydrologic Soil Group (AMC II)						
	A	AB	B	BC	C	CD	D
Cultivated Land (Fallow)	77	82	86	89	91	93	94
[2]**Cultivated Land** (Row Crops)							
---- without agricultural BMPs	72	77	81	85	88	90	91
---- [3]with agricultural BMPs	62	67	71	75	78	80	81
[4]**Cultivated Land (Small Grain)**							
---- without agricultural BMPs	65	71	76	80	84	86	88
---- with agricultural BMPs	59	65	70	74	78	80	81
[5]**Cultivated Land** (Close-seeded Legumes or Rotation Meadow)							
---- without agricultural BMPs	66	72	77	81	85	87	89
---- with agricultural BMPs	51	59	67	72	76	78	80
Pasture or Range Land							
---- [6]poor condition	68	74	79	83	86	88	89
---- [7]good condition	39	50	61	68	74	77	80
Meadow							
---- good condition	30	44	58	65	71	75	78

Land Use Description	Hydrologic Soil Group (AMC II)						
	A	AB	B	BC	C	CD	D
Wooded or Forest Land							
---- [8]poor cover	45	56	66	72	77	80	83
---- [9]good cover	25	40	55	63	70	74	77
Open Spaces, Lawns, Parks, Golf Courses, Cemeteries							
---- good condition (≥75% grass coverage)	39	50	61	68	74	77	80
---- fair condition (50% - 75% grass coverage)	49	59	69	74	79	82	84
Commercial and Business Areas (~85% impervious)	89	91	92	93	94	95	95
Industrial Areas (~72% impervious)	81	85	88	90	91	92	93
[10]**Residential Areas**							
---- ≤ 1/8 acre lot size (~65% impervious)	77	81	85	88	90	91	92
---- 1/4 acre lot size (~38% impervious)	61	68	75	79	83	85	87
---- 1/3 acre lot size (~30% impervious)	57	65	72	77	81	84	86
---- ½ acre lot size (~25% impervious)	54	62	70	75	80	83	85
---- 1 acre lot size (~20% impervious)	51	60	68	74	79	82	84
Paved Parking Lots, Roofs, Driveways	98	98	98	98	98	98	98
Streets and Roads							
---- paved with curb and storm sewer connection	98	98	98	98	98	98	98
---- gravel	76	81	85	87	89	90	91
---- dirt	72	77	82	85	87	88	89
[11]**Open Water Bodies** (Lakes, Wetlands, Ponds)	100	100	100	100	100	100	100

[1] Adapted from U.S. Soil Conservation Service National Engineering Handbook (1972), MTC Drainage Manual Chapter B (1984), MTO Drainage Management Manual (1997).

[2] Includes row crops such as soybeans, corn, sorghum hay, peanut, potato, etc.

[3] Includes agricultural best management practices (BMPs) such as contouring and terracing.

[4] Includes small grain crops such as winter wheat, spring wheat, durham wheat, barley, oats, rye, etc.

[5] Includes close-seeded legumes such as alfalfa, timothy grass, grass hay, etc.

[6] Poor condition is defined as heavily grazed, no mulch, or has plant cover on less than 50% of the area.

[7] Good condition is defined as lightly grazed, more than 75% of the area has plant cover.

[8] Poor cover is defined as heavily grazed or regularly burned so that litter, small trees and brush are regularly destroyed.

[9] Good cover is defined as protected from grazing so that litter and shrubs cover the soil.

[10] Curve numbers are calculated assuming that roof leaders are connected to the driveway and/or road with a minimum of additional infiltration.

[11] When a number of water bodies within a large multi-land use catchment is modeled, a CN value of 50 may be applied to the water bodies in calculating the area-weighted CN value. When isolating a water body and modelling as a separate catchment, then a CN value of 100 should be used and the catchment is typically routed through a reservoir.

Table 17 - Initial Abstraction/Depression Storage

Cover	Depth (mm)
Woods	10
Meadows	8
Cultivated	7
Rural Residential	5
Urban Residential	1.5
Industrial/Commercial	1

Adapted from UNESCO, Manual on Drainage in Urbanized Areas, 1987

Total Imperviousness (TIMP) and Directly Connected Imperviousness (XIMP)

Table 18 outlines typical parameter values that should be applied at the preliminary/conceptual design stage. The TIMP and XIMP values at the high end of the range given in Table 18 shall be used at the preliminary/conceptual design stage. Adjustment of parameter values will be considered and accepted by the City at the functional and detailed design stage subject to the submission of relevant engineering calculations from the consulting engineer to justify the revision of these parameters.

Table 18 - Typical Impervious Values by Land Use

Land Use	Total Impervious Percentage (TIMP)	Directly Connected Impervious Percentage (XIMP)
Low Density Residential (0.1 – 0.3 ha lot)	65%	55%
Medium Density Residential (0.04 – 0.1 ha lot)	70%	60%
High Density Residential (<0.04 ha lot)	85%	75%
Employment/Mixed Use/Community Node/Local Node	95%	95%
School/Recreation Centre	90%	80%
Park/Golf Course/Cemetary/Utility Corridor	0%	0%

An approximation of the total impervious fraction (TIMP) can be calculated using the following formula:

Equation 6 - Total Imperviousness Conversion Equation

$$TIMP = \frac{C - 0.2}{0.7}$$

where,

TIMP = total impervious fraction (dimensionless)

C = runoff coefficient

Infiltration

Infiltration is the movement of water from the ground surface into the soil. The most widely used methods for calculating infiltration include the SCS Curve Number Method, Horton's Method, and the Green-Ampt Method (MTO Drainage Management Manual, 1997).

SCS Curve Number Method

The SCS Curve Number Method is most appropriate for rural and natural basins.

Equation 7 - SCS Curve Number Method Equation

$$Q = \frac{(P - I_a)^2}{(P + S - I_a)}$$

where,

Q = runoff depth (mm)
P = precipitation (mm)
S = soil storage capacity (mm) = (25400/CN) – 254 (mm)
CN = curve number based on vegetative cover and hydrologic soil group (A, B, C, and D)
I_a = initial abstraction (mm)

CN ≤ 70	IA = 0.075(S)
70 < CN ≤ 80	IA = 0.10(S)
80 < CN ≤ 90	IA = 0.15(S)
CN > 90	IA = 0.2(S)

(Visual OTTHYMO Reference Manual, Version 2.0, July 2002)

Horton Infiltration Method

The Horton Infiltration Method is widely accepted for use within small urban catchments in areas without much soil variability. The Horton Infiltration Method is not ideally suited for use in rural and natural basins due to the large variation in soil and land cover types typically encountered. The Horton Infiltration Method is not recommended for storm durations greater than or equal to 12 hours as predicted flows are sometimes erroneous (VO2 Reference Manual, July 2002).

Equation 8 - Horton Infiltration Method Equation

$$f_t = f_\infty + (f_o - f_\infty)(e)^{-kt}$$

If $i < f_t$ then $f = i$

where,

f_t = infiltration rate (mm/hr)
f_∞ = minimum infiltration rate (mm/hr)
f_o = maximum infiltration rate (mm/hr)
e = natural logarithm
k = decay coefficient (1/hr)
t = time from beginning of precipitation (hr)
i = rainfall intensity (mm/hr)

The following table provides typical parameter values used in the Horton Infiltration Method.

Table 19 - Typical Parameter Values for Horton Infiltration Method

Parameter	HSG A	HSG B	HSG C	HSG D
f_o (mm/hr) (dry soil conditions)	250	200	125	75
f_∞ (mm/hr)	25	13	5	3
k (1/hr)	2	2	2	2

Source: M.L. Terstriep and J.B. Stall, Illinois Urban Drainage Area Simulator (ILLUDAS) Illinois State Water Survey Urbana, 1979.

Green-Ampt Infiltration Method

The Green-Ampt Infiltration Method has been used in Canada for both agricultural and urban watersheds.

When $F < F_s$, $f = i$

When $F > F_s$

Equation 9 - Green-Ampt Infiltration Method Equation

$$f_p = K_s \left[1 + \frac{(S_u)(IMD)}{F} \right]$$

where,

F = cumulative infiltration volume (mm)
F_s = cumulative infiltration volume required to cause surface saturation (mm)

Equation 10 - Green-Ampt Infiltration Method Equation

$$F_s = \frac{(S_u)(IMD)}{i/K_s - 1}$$ when $i > K_s$

F_s = no calculation when $i < K_s$
f = infiltration rate (mm/hr)
f_p = infiltration capacity (mm/hr)
i = rainfall intensity (mm/hr)
K_s = saturated hydraulic conductivity (mm/hr)
S_u = average capillary suction at the wetting front (mm)
IMD = initial moisture deficit for the event (mm/mm)

The following table provides typical parameter values used in the Green-Ampt Method.

Table 20 - Typical Parameter Values for Green-Ampt Infiltration Method

Parameter	HSG A	HSG B	HSG C	HSG D
IMD (mm/mm)	0.34	0.32	0.26	0.21
S_u (mm)	100	300	250	180
K_s (mm/hr)	25	13	5	3

Source: Design Chart 1.13, MTO Drainage Management Manual, 1997

6.3 Hydraulics

The hydraulic capacity of the storm drainage system can be determined through hydraulic modelling and for certain applications through the use of standard "hand calculations".

For larger (greater than 40 hectares) and more complicated sewersheds a dynamic model should be used for the dual drainage analysis. The dynamic computer model for a dual system analysis should simulate the Regulatory Storm, defined as the larger of the City of Pickering's 100 year storm (1 hour AES) or the Regional storm event.

A dynamic model will help ensure that a 5 year level of protection with no storage is provided for the 5 year storm and will also ensure that the sewer system is protected against critical surcharging during the Regulatory storm event.

When analyzing the capacity of an existing system, a dynamic computer model will provide more realistic results since it can account for effects of limited catchbasin capture, depression storage, times of concentrations and so on. When designing large collector storm sewer systems with drainage areas greater than 40 hectares, computer models or similar hydrograph based simulation methods must be used unless the engineer can provide adequate justification as to why an alternative method should be used. For smaller developments (i.e., less than 40 hectares) simplified methods can be used provided that conservative assumptions are made. In choosing a computer model, it is important that the engineer consider the data and model limitations, as noted in Section 6.1.

The Ontario Ministry of Natural Resources Floodplain Management in Ontario Technical Guidelines provides guidance on hydraulic models approved for use in Ontario. The following standards of practice should be used as a guide for hydraulic modelling:

1. The proponent should clearly identify the study objectives and how they relate to the hydraulic modelling.

2. The proponent should provide the purpose for the hydraulic modelling.

3. The modeller should provide the model selection criteria and how the model matches the criteria.

4. The proponent should provide plans clearly presenting the closed and/or open hydraulic system.

5. For plans describing the major system, the proponent should note.

6. Cross-sections, study limits, land use, crossing details, spill areas, ineffective flow areas, and flooding limits and elevations for the appropriate design event(s).

7. For plans describing closed systems such as storm sewers, the proponent should note the storm sewer network details including study limits, land use, manhole numbers, ground elevation, storm sewer size, inverts, length and slope.

8. For combined hydrologic/hydraulic models such as SWMM, the proponent should provide plans that describe the minor and major system and the respective drainage areas of each.

9. For all hydraulic models, the proponent should provide the downstream and, if applicable, upstream boundary conditions for each storm modeled and the assumptions used to define the boundary condition (e.g., water level in the creek/pond/receiving sewer, etc.).

10. For all hydraulic models, the proponent should document the parameters used to hydraulic losses such as Manning's "n", inlet and outlet losses, bend losses and other appropriate losses.

11. The proponent should summarize the selection of procedures for determining the computed energy grade line and water surface elevations.

12. The proponent should document the hydraulic results in summary form for the relevant storm events.

13. The proponent should model the major system such that it fully contains the modeled flows without exceeding the hydraulic cross-section. Should it not be possible to contain the flows within the defined geometry of the major system, the proponent should provide details on the spill characteristics.

14. The proponent should document potential impacts on existing infrastructure and possible mitigation measures.

15. Sensitivity analysis should be conducted on a limited number of parameters depending on the model type and complexity.

16. The proponent should, if possible, verify hydraulic results for the existing major/minor system by documenting historical flood elevations for specific storm events and comparing the hydraulic modelling results to the historical data; calibration of losses should be included, if sufficient data exists.

17. The proponent should provide the input and output data in a logical manner with an explanation of the potential error.

The hydraulic capacity of storm sewers is to be determined using the City of Pickering's Storm Sewer Design Sheet (P-500). The proponent should document, in both plans and in text, the hydrology for the storm sewer design. The storm sewer design should be completed using the City of Pickering's 5 year IDF storm data (Table 12).

6.3.1 Minor System Hydraulic Calculations and Hydraulic Grade Line Analysis

Head losses in storm sewers occur as a result of friction losses and form losses (minor losses). Friction losses are the result of shear stress between the moving fluid and the boundary material. Form losses are the result of abrupt transitions due to the geometry of maintenance holes, bends, expansions and contractions.

The 100 year hydraulic grade line (HGL) is considered to be the HGL for the storm sewer during the City of Pickering's 100 year design storm. While it is recognized that storm sewers and catchbasin spacing designed using the City of Pickering criteria may or may not capture the 100 year event, the onus is on the consultant to demonstrate the actual flow capture within the proposed storm sewer system using a dual drainage approach to split runoff into both major and minor system flows. Alternatively, the 100 year flow can assumed to be captured. These flows shall then be used in the HGL calculations.

Where an HGL analysis is required, a spreadsheet or equivalent method using computer modelling (e.g., PCSWMM) shall be used that includes design information including storm sewer sizes, lengths and inverts, tailwater elevations, flow, and velocities to calculate the losses that will occur through the storm sewer system. The use of modelling software requires prior consultation and approval by the City.

When completing a dual drainage analysis using a spreadsheet approach, minor system capture shall be based on MTO design charts (MTO Drainage Management Manual, 1997) for catchbasin inlets within the roadway under sag or sloped conditions. Carryover flow shall be accounted for at downstream catchbasins where inlet capacity is exceeded.

When completing a dual drainage analysis using a model, rating curve calculations will be required to determine the amount of total flow captured to the minor system based on the number and type of inlet catchbasins. The rating curve calculations shall be completed assuming no blockage at road inlets and sags.

When completing HGL calculations using either a spreadsheet approach or computer modelling, the starting elevation for the HGL calculation shall be the higher of the 100 year water surface elevation within the receiving system (downstream SWM Pond, watercourse, etc.) or the obvert of the outlet pipe from the system. The HGL is to be plotted on all plan and profile drawings and calculations provided.

All storm sewer pipes and maintenance holes must be accounted for, along with the drainage area to each maintenance hole. Hydraulic losses must also be accounted for in the minor system, either using a hydraulic model or using the head loss equations provided below with the spreadsheet method.

When completing spreadsheet calculations, head losses through the storm sewer system shall be calculated using Bernoulli’s equation of head loss in the form of:

Equation 11 - Bernoulli's Equation

$$h = \frac{kV^2}{2g}$$

where,

h = head loss (m)
k = loss coefficient (dimensionless)
V = average pipe flow velocity (m/s)
g = gravitational constant, (9.81 m/s^2)

For the frictional component of the losses through the pipe, the k coefficient becomes:

Equation 12 – Friction Loss Coefficient Equation

$$k = \frac{fL}{D}$$

where,

k = loss coefficient (dimensionless)
f = friction factor (dimensionless)
L = length of storm sewer (m)
D = actual diameter of the pipe (m)

The friction factor is defined by:

Equation 13 - Friction Factor Equation

$$f = 124 \frac{n^2}{d^{1/3}}$$

where,

f = friction factor (dimensionless)
n = Mannings n (dimensionless)
d = actual diameter of the pipe (m)

Head losses through maintenance holes shall be calculated using Bernoulli’s equation of head loss, as outlined above, with an appropriate value of k consistent with the type of junction (Design and Construction of Urban Stormwater Management Systems, ASCE, 1992, p.146 – 159).

For a straight through maintenance hole, with one incoming and one outgoing pipe, the loss shall be calculated as follows:

Equation 14 - Maintenance Hole Head Loss Equation

$$h_{MH} = 0.05 \frac{V_d^{\,2}}{2g}$$

where,

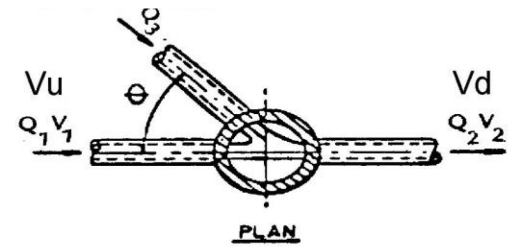
h_{MH} = head loss through the maintenance hole (m)
0.05 = loss coefficient, k (dimensionless)
V_d = average pipe flow velocity in the downstream sewer (m/s)
g = gravitational constant, (9.81 m/s^2)

For a junction maintenance hole, with an incoming pipe, outgoing pipe and 1 or more laterals, the loss shall be calculated based on the velocities in the main branch sewers and the angle of the lateral sewer to the main branch as follows:

Equation 15 - 15° Lateral MH Head Loss Equation

15° lateral:

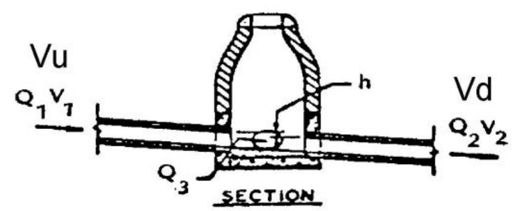
$$h_{MH} = \frac{V_d^{\,2}}{2g} - 0.85 \frac{V_u^{\,2}}{2g}$$



Equation 16 - 22.5° Lateral MH Head Loss Equation

22.5° lateral:

$$h_{MH} = \frac{V_d^{\,2}}{2g} - 0.75 \frac{V_u^{\,2}}{2g}$$



Equation 17 - 30° Lateral MH Head Loss Equation

30° lateral:

$$h_{MH} = \frac{V_d^{\,2}}{2g} - 0.65 \frac{V_u^{\,2}}{2g}$$

Equation 18 - 45° Lateral MH Head Loss Equation

45° lateral:

$$h_{MH} = \frac{V_d^{\,2}}{2g} - 0.50 \frac{V_u^{\,2}}{2g}$$

Equation 19 - 60° Lateral MH Head Loss Equation

60° lateral: $$h_{MH} = \frac{V_d^{\ 2}}{2g} - 0.35\frac{V_u^{\ 2}}{2g}$$

Equation 20 - 90° Later MH Head Loss Equation

90° lateral: $$h_{MH} = \frac{V_d^{\ 2}}{2g} - 0.25\frac{V_u^{\ 2}}{2g}$$

where,

h_{MH} = head loss through h the maintenance hole (m)
V_d = average pipe flow velocity in the downstream main branch sewer (m/s)
V_u = average pipe flow velocity in the upstream main branch sewer (m/s)
g = gravitational constant (9.81 m/s^2)

For a maintenance hole, with an incoming and outgoing pipe benched through 90°, the loss shall be calculated based on the radius of curvature of the benching as follows:

Equation 21 - MH Head Loss Equation - Radius = Pipe Diameter

Radius = the diameter of the pipe: $$h_{MH} = 0.50\frac{V_d^{\ 2}}{2g}$$

Equation 22 - MH Head Loss Equation - Radius = 2 to 8 Times Pipe Diameter

Radius = 2 to 8 times the diameter of the pipe: $$h_{MH} = 0.25\frac{V_d^{\ 2}}{2g}$$

Equation 23 - MH Head Loss Equation - Radius = 8 to 20 Times Pipe Diameter

Radius = 8 to 20 times the diameter of the pipe: $$h_{MH} = 0.40\frac{V_d^{\ 2}}{2g}$$

where,

h_{MH} = head loss through the maintenance hole (m)
V_d = average pipe flow velocity in the downstream sewer (m/s)
g = gravitational constant (9.81 m/s^2)

6.3.2 Major System Drainage Capture and Dual Drainage Analysis

Where major system drainage capture is required due to the Region of Durham criteria of not crossing Regional Road with overland flow, the dual system analysis shall simulate the 1 hour AES 100 year storm. The analysis is to be based on detailed engineering design information and on a segment by segment basis as per modeling practice. The external areas may be considered on a lumped basis with supporting assumptions.

All road and sag inlets are to be modeled based on the approach flow (depth), inlet capture capabilities and sag storage characteristics. Inlets at sags and low points are to assume 50% blockage. Variations from standard inlet spacing and types must be documented and approved by the City. Volume and flow continuity are to be maintained and documented according to the modeling results. The maximum ponding depth at sags and low points prior to overtopping must be maintained on public property and not encroach onto private property.

For sizing of the emergency overflow route, 50% blockage is to be assumed at all road inlets and 100% blockage is to be assumed at all sag/low point inlets. This emergency overflow modeling scenario should include overflow routes/spill points. When overflowing onto a Regional road, the Maximum Lateral Spread Distance for a roadway with two lanes in each direction shall be such that a minimum of one lane remains open in each direction. The sizing calculations of the emergency overland flow route shall be provided for review.

6.3.3 Culvert/Bridge Hydraulic Analysis

Bridge and culvert calculations should be completed by computer programs such as CulvertMaster and HEC-RAS. CulvertMaster is suitable for completing capacity and headwater elevation calculations for culverts, while HEC-RAS is more appropriate for completing similar hydraulic calculations associated with bridges. When completing hydraulic analyses with HEC-RAS, the location of cross sections and modelling conventions should be in accordance with the HEC-RAS User Manual and Reference Manual.

7.0 Construction Sediment and Erosion Control Methods

Sediment and erosion control measures that can be implemented within the City of Pickering shall be consistent with the Greater Golden Horseshoe Area Conservation Authorities Erosion and Sediment Control Guidelines for Urban Construction (ESC Manual) (TRCA, 2006). Implementation details for certain sediment and erosion controls are covered under the Ontario Standard Specifications (OPSS) 577. Due to the presence of endangered species in the rivers and streams in Pickering, the TRCA and MNRF should be consulted to ensure that sediment and erosion controls are adequate.

The SWM report shall include a list of items in terms of controlling erosion and the transport of sediment into natural watercourses during construction. The following is a general list of requirements; however, since the list is intended to cover a broad range of development proposals, portions of the list may not be applicable for all development proposals:

- Erosion and Sediment Control Plans
- Erosion and Sediment Control Phasing
- Worksite Isolation Plan for In-stream Construction
- Spill Control and Response Plan
- De-watering Plan
- Storm Drain Outfall Protection
- Storm Drain Inlet Protection
- Seeding/Sodding
- Sediment/Silt Control Fence
- Interception/Diversion Swales and Dykes
- Vehicle Tracking Control/Mud Mats
- Sediment Traps
- Rock Check Dams
- Temporary Sediment Control Ponds/Basins
- Topsoil Stockpiles
- Construction Access Mud Mats
- Restoration

The design of erosion and sediment control measures shall be in accordance with the City of Pickering Fill and Topsoil Disturbance By-law (6060/02) and permit requirements as well as the ESC Manual and with applicable City of Pickering standards.

It should be noted that the City does not allow over-excavation of the ultimate stormwater management pond to allow the facility to be used as the sediment and erosion control pond.

Development which occurs in the catchment area of a City-owned facility cannot discharge drainage to the facility until construction is complete and the site has been stabilized.

If the site area to be disturbed is less than 2 hectares, sediment control fences and cut-off swales or equivalent measures shall be placed along all downslope site boundaries during periods of land disturbance to reduce erosion. Inactive disturbed land should be stabilized by seeding, sodding, mulching, covering, or with other control measures within 30 days.

For proposed developments with areas larger than 2 hectares disturbed at a time, a sediment control pond shall be designed as per the current TRCA criteria which is provided in the ESC Manual and summarized below:

1. Pond side slopes to be stabilized immediately.
2. Minimum 48 Hour drawdown time with minimum 75mm diameter orifice.
3. Active Storage Volume
    - Should be designed with a minimum of 125 m^3/hectare contributing drainage area with a minimum 48 hour drawdown time (minimum 75 mm diameter orifice) and minimum 4:1 length-to-width ratio.
4. Permanent Pool Volume
    - Minimum 125 m^3/hectare drainage area.
    - Minimum 185 m^3/hectare drainage area if length-to-width ratio is less than 4:1 or the drawdown time for the active storage is less than 48 hours.

Inactive disturbed land should be stabilized by seeding, sodding, mulching, covering, or with other control measures within 30 days.

All Erosion and Sediment Control Facilities are to be inspected by the Consultant once a week, after each rainfall in excess of 25 mm and after a significant snowmelt. Daily inspections are required during extended rainfall or snow melt periods. These inspections are to ensure that the facilities are in proper working condition and all damaged Erosion and Sediment Control facilities are to be repaired and/or replaced within 48 hours of the inspection.

8.0 Engineering Submission Reporting Requirements (Drainage Designs, SWM Reports, Operation and Maintenance Manuals)

A complete submission package must be delivered to the City for detailed engineering review of SWM Plans for both the conceptual/preliminary design stage and the detailed design stage. Submissions at the conceptual/preliminary design stage will consist of a Preliminary SWM Report, Functional SWM Report, or Functional Servicing Report. Submissions at the detailed design stage will consist of a SWM Report and an Operation and Maintenance Manual.

The specific content requirements for the 2 types of SWM Plans and Operation and Maintenance Manual submissions is provided below. However, as the list is intended to cover a broad range of development proposals, some of the items may not be applicable for infill development or small site plans. Exemptions may be made on a site-by-site basis, through pre-consultation with the City.

In general, printed and digital copies of the SWM Plan and Operation and Maintenance Manual must be submitted with each development proposal. Digital copies are to be submitted in original format, and include report text, drawings and appendices, as well as the full set of engineering drawings (for detailed design). Reports must be signed and sealed by a Licensed Professional Engineer of Ontario and include, as a minimum, the items outlined below.

8.1 Guidelines on the Use of the Engineers' Seal

Practitioners should familiarize themselves with the PEO guidelines on the Use of the Professional Engineer's Seal (PEO, 2008), exerts of which are provided below:

- Engineers must seal all final documents that are within the practice of professional engineering, provided as part of a service to the public. This includes all documents containing engineering calculations, expressing engineering opinions, or giving instructions based on engineering judgment.

- Seals must be affixed to drawings, specifications, or sketches accompanying change notices and site instructions, and studies containing technical information or engineering direction. Reports providing technical information or engineering direction to the user must be signed and sealed. Drawings bound into reports need not be sealed individually, provided the document itself is signed, sealed and dated.

- Professional responsibility refers to engineers' obligations to conduct themselves in accordance with the technical, legal and ethical standards of the profession, including the higher duty of care associated with professional status. Whenever individuals act in their capacity as professional engineers, they must be prepared to answer for their conduct in discharging their obligations to the profession and to the public. The seal is an indication of who is taking professional responsibility for the content of a document.

- By affixing the seal, a professional engineer agrees to take the responsibility and to be accountable for any deficiency of skill, knowledge or judgment found in his or her work. Should a complaint be made regarding a document that is alleged to demonstrate negligence or incompetence, the engineer who seals the document is answerable to Professional Engineers of Ontario.

- Accepting this responsibility is part of the commitment made by each individual when accepting the exclusive right to practise afforded by the professional engineer's licence. Consequently, the use of the seal is not optional. Failing to seal an engineering document provided as part of service to the public is a violation of the *Professional Engineers Act*. The implications associated with failing to seal a final drawing are the same as any act of professional misconduct: The P.Eng. would be disciplined by PEO, and there have been discipline cases in which one of the charges was failing to seal.

8.2 Submissions to External Agencies

Submissions shall be made to the following external agencies as required:

- Toronto and Region Conservation Authority (TRCA). TRCA is typically circulated on all applications that potentially impact the ecological resources and the quality and quantity of stormwater runoff and baseflow to watercourses within the jurisdiction of the TRCA.

- Ministry of the Environment, Conservation and Parks (MECP) District Office or Client Services and Permissions Branch. The MECP is typically circulated on applications for which Environmental Compliance (ECA) is required for municipal and private water and sewage works such as SWM facilities.

- Ministry of Natural Resources and Forestry (MNRF). The MNRF is typically circulated on applications in which a permit is required under the *Lakes and Rivers Improvement Act* for construction within a watercourse.

- Ministry of Transportation (MTO). The MTO is typically circulated on applications in which provincial roads/highways under the authority of the MTO may be directly or indirectly impacted by the proposed works (400 m each side). For example, proposed development adjacent provincial roads/highways that may impact future expansion of travel corridors or may impact flows under MTO culverts or level of flood protection, typically require MTO review and approval.

- As directed by the City of Pickering.

8.3 Guidelines on Responses to Comments

Development proponents shall provide an itemized response letter to address City comments in addition to any required revisions to reports, drawings, calculations and/or any additional studies which may be required.

The format of the response letter shall have the City's comment in italics with the development proponent's response below. The development proponent's response to the comment should directly address the issue raised in the City's comment. Where a technical comment has been provided it must be addressed through a technical answer with supporting documentation (calculations, drawings, etc.), as required. Development proponents should avoid providing overly general responses which do not directly address the intent of the comment. If a comment has not been adequately addressed the City will repeat the technical comment and request a resubmission.

Development proponents are encouraged to discuss their questions and concerns with City staff prior to completing a resubmission to reduce the potential for delays in the approval process.

Where supplemental supporting documentation (i.e., guidelines, manuals and technical documents) are being used to support a design decision the supporting documentation must follow examples of "good engineering practice" within Canada or the United States.

Good engineering practice comprises well-known, widely available and generally acceptable behavior proven by long-standing, consistent and general use exhibited by the majority of practitioners working regularly in that area of practice (PEO, 2009).

8.4 Reporting Requirements for Conceptual/Preliminary SWM Plans (Preliminary SWM Report, Functional SWM Report, Functional Servicing Report)

SWM Plans typically submitted to the City in support of site plan and plan of subdivision applications at the conceptual/preliminary design stage include Preliminary SWM Reports, Functional SWM Reports or Functional Servicing Reports. Upon review of these reports along with other miscellaneous required supporting documents by the City and Conservation Authority, and once any comments have been satisfactorily addressed, Conditions of Draft Plan Approval are typically issued. The specific requirements that must be included in such reports submitted to the City shall include, as a minimum, the items outlined below:

Background Information

- Introductory material describing the property location, including both municipal and legal descriptions, planning status, proposed development scheme, construction phasing plan, intent of the report, and existing/historical land use.
- Reference for the topographic information used to determine internal and external catchment areas under existing and proposed conditions as well as references for soils, and water surface elevations (WSEL's) adjacent the site and downstream of any proposed outfalls or SWM facility outlet structures.
- Relevant recommendations and requirements from the Master Drainage Plan (if applicable) must be summarized for the site.
- Information related to the Class Environmental Assessment process must be included, if applicable.
- A copy of the Draft Plan must be provided.

Storm Drainage Areas

- Pre-development conditions must be indicated including: internal and external catchment areas and catchment I.D.'s with drainage patterns indicated.
- Post-development conditions must be provided including: internal and external catchment areas and catchment I.D.'s, and major and minor flow routes for the site and relevant external lands.

Stormwater Management Targets/Objectives and Design Criteria

- Conceptual/Preliminary SWM reports should identify how applicable recommendations from Master Drainage Plans, geotechnical and hydrogeological reports have been incorporated into the design.

- Outline the SWM design criteria being applied in the report. This should include criteria for water quality, erosion and quantity control as well as infiltration (water balance).

Storm Drainage System Design

- A conceptual storm sewer design must be provided to ensure sufficient sewer slope and pipe cover. Major overland flow paths should be indicated and any capacity restriction should be identified.

- Any interim servicing conditions should be identified.

- The routing of any external flows through the site must be identified.

SWM Facility Design

- Pre-development conditions must be indicated including: hydrologic parameters used for modelling, and pre-development peak flow rate for the erosion control event (i.e., 25 mm 4 hour Chicago storm or subwatershed specific criteria) and pre-development peak flow rates for the 2 year, 5 year, 10 year, 25 year, 50 year, and 100 year design storms for the critical storm distribution and duration (i.e., must look at 1 hour and 12 hour AES distributions) for each sub catchment.

- Post-development conditions must be provided including: hydrologic parameters used for modelling, and post-development peak flow rate and detention time for the erosion control event (i.e., 25 mm 4 hour Chicago storm or subwatershed specific criteria) and post-development peak flow rates for the 2 year, 5 year, 10 year, 25 year, 50 year, and 100 year design storms for the critical storm distribution and duration (i.e., must look at 1 hour and 12 hour AES distributions) for each sub catchment. A table summarizing the critical storm analysis must be included in support of the storm selected for SWM facility design.

- Any requirements for thermal mitigation measures must be identified and conceptually described for any proposed SWM facilities.

- The water balance methodology must be provided along with input parameters, summary of results, and the requirements and concepts for any proposed infiltration measures.

- It must be demonstrated conceptually that sufficient measures can be provided to meet the required level of water quality control per the established criteria.

- It must be demonstrated conceptually that sufficient measures can be provided to achieve the required level of erosion control per the established criteria.

Erosion and Sediment Control During Construction

- Requirements and concepts for erosion and sediment control measures during construction are to comply with the City of Pickering Fill and Topsoil Disturbance By-law 6060/02 and should be identified in the design drawing package.

SWM Facility Inspection and Maintenance Requirements

- A description of proposed inspection and maintenance requirements to ensure that the SWM facilities will continue to operate as designed must be provided.

Primary Tables

- Stage vs. Discharge and Storage Table (if required) – The table should include, as a minimum, all points used in the reservoir routing command.

- SWM facility operation characteristics table must be provided for the conceptual level of detail, including pond bottom, normal water level (NWL), extended detention WL, high water level (HWL) and incremental and cumulative storage volumes. A conceptual storage-discharge rating curve table must be included.

- A comparison of pre-development, uncontrolled post-development and controlled post-development flows table – showing peak flows for the 2 year through 100 year design storm events at significant points of interest throughout the catchment area.

- Comparison of pre-development, unmitigated post-development and mitigated post-development water balance volumes and infiltration volumes.

Primary Figures and Drawings

- Site Location Plan
- Draft Plan
- Hazard Area Mapping (if applicable)
- Pre-development internal and external catchment areas and catchment I.D.'s on a topographic base showing existing land use and drainage patterns.
- Post-development internal and external catchment areas and catchment I.D.'s on a topographic base showing future land use, and major and minor flow routes.
- Conceptual drawings and siting of any proposed SWM facilities, including location of inlet, outlet and spillway. NWL and HWL must be indicated on the conceptual drawings.
- Conceptual siting and details for any proposed infiltration measures.
- Conceptual siting and details for any proposed thermal mitigation measures.
- Full set of folded Engineering Conceptual/Preliminary Design Drawings, signed and sealed by a licensed Professional Engineer of Ontario.

Supporting Hydrology and Hydraulics Calculations and Modelling Details and Output

- Printed copies of the model schematics and hydrologic modelling, including input and detailed output files for the 2-yr through 100-yr return period events (i.e., must look at 1 and 12 hour AES distributions), 25 mm 4 hour Chicago storm or subwatershed specific erosion control criteria for existing and future land uses as required.
- Digital copies of all modelling are to be included with the report. Digital files must include all files necessary to run the model, (i.e., both input and storm files) as well as the detailed output files generated for the erosion event and 2 year through 100 year design storm events. Digital files are to include both pre and post-development scenarios.
- Relevant Storm Design Parameters Table - Identifying the design storm duration and distribution used.
- Table should be provided comparing the pre and post development peak flows for different storm distributions and durations for the site and required storage volumes to determine the critical storm to be used.
- Soil Characteristics Table – Listing the areal distribution of each soil type (expressed as a %) within every subcatchment.

- Model Input Parameters Table - Summarizing key input parameters for existing and future land use for each catchment including subcatchment I.D., drainage area, CN, IA, Tp, Slope, % impervious, modelling time step, pervious and impervious Manning's roughness, etc.

- Model input parameters, i.e., CN, IA, Tc, % imperviousness, etc., calculations.

- Incremental and cumulative volume calculations for the SWM facility.

- Drawdown time calculations for SWM facility (if applicable).

- Water balance calculations showing pre-development, unmitigated post-development and mitigated post-development infiltration volume analysis.

- Pre and post-development watershed modelling schematics reflecting the model subcatchment I.D.'s and catchment areas.

Stand Alone Reports

- Geotechnical Report providing borehole information, including existing groundwater conditions, for the site and proposed pond block (if applicable).

- Environmental reports (e.g., fisheries impacts, hydrogeology, fluvial geomorphology), if applicable.

8.5 Reporting Requirements for Detailed SWM Plans (Detailed Design)

SWM plans typically submitted to the City in support of site plan and plan of subdivision applications at the detailed design stage consist of a SWM Report. Upon review and approval of the SWM Report along with other miscellaneous required supporting documents by the City, Conservation Authority and Provincial/Federal agencies, as required, Plan of Subdivision Approval and Registration is typically provided. The specific requirements that must be included in SWM Reports submitted to the City shall include, as a minimum, the items outlined below:

Background Information

- Introductory material describing the property location, including both municipal and legal descriptions, planning status, proposed development scheme, construction phasing plan, intent of the report, and existing/historical land use.

- Reference for the topographic information using the City of Pickering horizontal and vertical control monuments used to determine internal and external catchment areas under existing and proposed conditions as well as references for soils, and water surface elevations (WSEL's) adjacent the site and downstream of any proposed outfalls or SWM facility outlet structures.

- Information related to the Class Environmental Assessment process must be included, if applicable.

Storm Drainage Areas

- Pre-development conditions must be indicated including: internal and external catchment areas and catchment I.D.s with drainage patterns indicated.

- Post-development conditions must be provided including: internal and external catchment areas and catchment I.D.s, and major and minor flow routes for the site and relevant external lands.

SWM Targets/Objectives and Design Criteria

- SWM reports should identify how applicable recommendations from Master Drainage Plans (if applicable), geotechnical and hydrogeological reports have been incorporated into the design.

- Outline the SWM design criteria being applied in the report. This should include criteria for water quality, erosion and quantity control as well as infiltration (water balance).

Storm Drainage System Design

- It must be shown that the site provides safe conveyance of both the minor storm and regulatory flows from both the subject site and any external lands, through the development to a sufficient outlet, with no adverse impact to either the upstream or downstream landowners. A sufficient outlet constitutes: a permanently flowing watercourse or lake; a public right of way (provided the proponent has obtained written permission to discharge storm flows from the land owner); or in the case of privately owned lands, a legal right of discharge registered on title.

- Any interim servicing conditions should be identified.

SWM Facility Design

- Pre-development conditions must be indicated including: hydrologic parameters used for modelling, and pre-development peak flow rate for the erosion control event (i.e., 25 mm 4 hour Chicago storm or subwatershed specific criteria) and pre-development peak flow rates for the 2 year, 5 year, 10 year, 25 year, 50 year, and 100 year design storms for the critical storm distribution and duration (i.e., must look at 1 hour and 12 hour AES distributions) for each sub catchment.

- Post-development conditions must be provided including: hydrologic parameters used for modelling, and post-development peak flow rate and detention time for the erosion control event (ie. 25 mm 4 hour Chicago storm or subwatershed specific criteria) and post-development peak flow rates for the 2 year, 5 year, 10 year, 25 year, 50 year, and 100 year design storms for the critical storm distribution and duration (i.e. must look at 1 hour and 12 hour AES distributions) for each sub catchment. A table summarizing the critical storm analysis must be included in support of the storm selected for SWM facility.

- The WSEL’s adjacent the site and downstream of the SWM facility outlet structure must be indicated to ensure the appropriate hydraulic calculations should backwater conditions exist.

- If required, thermal mitigation measures must be clearly identified and described for any proposed SWM facility.

- The water balance methodology must be provided along with input parameters, summary of results, proposed siting, and functioning of any proposed infiltration measures.

- It must be demonstrated that sufficient measures are provided to meet the required level of water quality control per the established guidelines.

- It must be demonstrated that sufficient measures are provided to achieve the required level of erosion control per the established guidelines.

Erosion and Sediment Control During Construction

- Description of proposed erosion and sediment control measures to be in place before, during and after municipal servicing construction up to the end of the servicing maintenance period, including schedule for implementing/decommissioning and maintenance requirements.

SWM Facility Inspection and Maintenance Requirements

- Description of proposed inspection and maintenance requirements to ensure that the SWM facilities will continue to operate as designed must be included in an Operation and Maintenance Manual. A schedule and frequency of maintenance activities is required.

Primary Tables

- Stage vs. Discharge and Storage Table (if required) – The table should include, as a minimum, all points used in the reservoir routing command.

- Existing and proposed runoff coefficients for each catchment.

- SWM Facility Operation Characteristics and Summary of Significant SWMF Features Table(s) - These include type of facility, contributing drainage area, lumped catchment imperviousness ratio, permanent pool, extended detention and quantity control volumes, as well as elevations for base of pond, base of forebay, normal water level, quality/erosion control level and active storage design high water level, 100 year design storm high water levels, and top of berm, inlet and outlet structure design details, such as: pipe size, orifice size, weir length, and invert elevation, and total draw down time required for the extended detention volume.

- A comparison of pre-development, uncontrolled post-development and controlled post-development flows table – showing peak flows for the 2 year through 100 year design storm events at significant points of interest throughout the catchment area.

- Comparison of pre-development, unmitigated post-development and mitigated post-development water balance volumes and infiltration volumes.

Primary Figures and Drawings

- Site Location Plan
- Pre-development internal and external catchment areas and catchment I.D.'s on a topographic base showing existing land use and drainage patterns.
- Post-development internal and external catchment areas and catchment I.D.'s on a topographic base showing future land use, and major and minor flow routes.
- Siting and details for any proposed infiltration measures and SWM facilities.
- Siting and details for any proposed thermal mitigation measures.
- Full set of folded Engineering Detailed Design Drawings, signed and sealed by a licensed Professional Engineer of Ontario.

Supporting Hydrology and Hydraulics Calculations and Modelling Details and Output

- Calculations demonstrating that all minor and major system storm outlets have sufficient energy dissipation and/or erosion protection based on calculated erosive velocities at each outlet.
- Storm sewer design sheets must be provided.
- Printed copies of the model schematics and hydrologic modelling, including input and detailed output files for the 2 year through 100 year return period events (i.e., must look at 1 and 12 hour AES distributions) and 25 mm 4 hour Chicago storm or subwatershed specific erosion control criteria for existing and future land uses as required.
- Digital copies of all modelling are to be included with the report. Digital files must include all files necessary to run the model, (i.e., both input and storm files) as well as the detailed output files generated for the relevant erosion event and 2 year through 100 year design storm events. Digital files are to include both pre and post-development scenarios.
- Relevant Storm Design Parameters Table - Identifying the design storm duration and distribution used.
- Table should be provided comparing the pre and post-development peak flows for different storm distributions and durations for the site and required storage volumes to determine the critical storm to be used.
- Soil Characteristics Table – Listing the areal distribution of each soil type (expressed as a %) within every subcatchment.

- Model Input Parameters Table - Summarizing key input parameters for existing and future land use for each catchment including subcatchment I.D., drainage area, CN, IA, Tp, Slope, % impervious, modelling time step, pervious and impervious Manning’s roughness, etc.

- Model input parameters - Include, with supporting documentation (figures and/or calculations) how each of the model parameters were calculated (i.e., CN, IA, Tp, % imperviousness, etc.)

- Conveyance capacity calculations for the major system flow path.

- Stage-Storage-Discharge spreadsheet with hydraulic calculations for any proposed outlet control structures. (Note: Calculation equations, coefficients, and design values for all hydraulic structures should be clearly identified).

- Incremental and cumulative volume calculations for the stormwater management facility.

- Sizing of emergency spillway (if applicable) for Regulatory Storm flows.

- Drawdown time calculations for SWM facilities (if applicable).

- Sizing of erosion control structures.

- Water balance calculations showing pre-development, unmitigated post-development and mitigated post-development infiltration volume analysis.

- Calculations demonstrating that any proposed infiltration measures will provide the required infiltration volumes for the site.

- Dual drainage and hydraulic grade line calculations in hard copy and digital format.

- Tailwater elevations must be indicated for the outlet of any storm sewer and/or proposed SWM facility to demonstrate that any backwater conditions have been properly accounted for in the hydraulic design of the conveyance structures.

- Pre and post-development watershed modelling schematics reflecting the model subcatchment I.D.’s and catchment areas.

- Pre and post-development hydrograph plots for all significant points of interest.

Stand Alone Reports

- Operation and Maintenance Manual including a monitoring program plan for priority SWM facilities indicating how the facility will be monitored including water quality on a periodic basis.

- Geotechnical Engineering Report providing borehole information for the site and proposed pond block (if applicable) and certifying geotechnical feasibility of any stormwater management facilities and identifying any liner requirements for proposed SWM facilities.

- Environmental reports (e.g., fisheries impacts, hydrogeology, fluvial geomorphology), if applicable.

- Reports shall be submitted in PDF format.

8.6 Reporting Requirements for SWM Facility Operation and Maintenance Manuals (Detailed Design)

Prior to final Site Plan or Plan of Subdivision approvals at the detailed design stage, an Operation and Maintenance Manual shall be prepared for all proposed SWM facilities. The specific requirements that must be included in SWM facility Operation and Maintenance Manuals submitted to the City shall include, as a minimum, the items outlined below:

Background Information

- Introductory material describing the property location, including both municipal and legal descriptions, and drainage area tributary to the facility.

SWM Facility Design Elements and General Description of Operation

- A general description describing the operation of the SWM facility and applicable water quality, erosion and quantity control criteria.
- Indicate and describe the various design elements of the SWM facility (e.g. sediment forebay, permanent pool, extended detention and flood storage, drawdown time and how the facility operates under various storm events, inlet and outlet control structures including maintenance by-pass valve, drawdown valve and spill containment valve, if applicable).

Responsibility for Maintenance Activities

- Provide details as to who is responsible for SWM facility maintenance before and following assumption by the City.

SWM Facility Inspection and Maintenance Procedures Prior to and Following Assumption

- Prepare a list of key inspection items including but not limited to the following:
    - check inlet and outlet structures for accumulation of miscellaneous construction debris and other trash that may affect performance
    - check for unusually long extended detention drawdown time that could indicate a blockage in the outlet structure
    - check for sediment accumulation in the forebay and downstream of the facility
    - note evidence of seepage along the berms
    - check for vandalism including illegal access (e.g., gates) or encroachment about the perimeter of the facility
    - confirm that safety and security measures are in good working order

- check for the presence of any unusual erosion around berms and inlet or outlet structures

- complete visual inspection to confirm that vegetation is healthy

- complete visual inspection to confirm no oil sheen present on water surface or the presence of other visible contaminants or odours

- check drawdown valve and spill containment valve (if applicable) for proper operation

- Provide recommended maintenance procedures for items including but not limited to the following: grass cutting; weed control; upland and fringe plantings; shoreline fringe plantings; aquatic vegetation replanting; outlet adjustments; bathymetric survey to assess the need for sediment removal; trash removal; and, winter maintenance.

SWM Facility Monitoring Program and Performance Evaluation Prior to Assumption

- Prepare a recommended plan for water quality monitoring that will accurately characterize the average water quality treatment provided by the SWM facility and demonstrate that it is in accordance with the MECP Environmental Compliance Approval.

- Include recommended procedure to verify the rating curve of the outlet control structure.

- Provide a recommended plan to complete a SWM facility bathymetric survey to determine the quantity of sediment to be removed (if any).

- Include a list of key structures to confirm as-constructed elevations and dimensions (e.g., inlet, outlet control structure components including weirs and orifices) and proper installation (e.g., safety and security measures, vegetation, erosion protection).

Procedure for Permanent Pool Drawdown and Removal, Handling and Disposal of SWM Facility Sediments

- Indicate the procedure required to dewater the permanent pool prior to sediment removal and how to divert storm flows away from the facility during maintenance operations.

- Provide a sediment handling, removal and disposal plan including but not limited to the following: written notification to residents within 120 m of the SWM facility identifying maintenance works and duration; erosion and sediment control plan to prevent the release of TSS to the downstream receiver; treatment, sediment dewatering and drying techniques to be used; and, the required chemical analyses to be completed in accordance with Ontario Regulation 558/00 prior to disposal.

Estimated Annualized Operation and Maintenance Costs

- Provide calculations of the estimated annualized operation and maintenance costs for the SWM facility. Costs should include but not be limited to the following: debris and litter removal; grass cutting and weed control (if applicable); maintenance of aquatic/shoreline fringe and upland/flood fringe vegetation; sediment testing; sediment removal and disposal; inlet/outlet structure repairs; side slope and access road repairs; and, retaining wall repairs.

Primary Tables and Supporting Calculations

- SWM facility inspection check list
- Estimated annualized operation and maintenance costs and supporting calculations
- Sediment accumulation and cleanout frequency calculations

Primary Figures and Drawings

- SWM facility location plan
- Post-development drainage area plan tributary to the SWM facility
- SWM facility stage-storage-discharge relationship and curve
- General plan for the SWM facility and detailed drawings of key elements (e.g., inlet, outlet control structure, maintenance valve, spill containment valve)

8.7 Design Documentation for Natural Channel Design

The following code of practice is considered a minimum for documentation of natural channel design and is not intended to be exhaustive:

1. The proponent should provide the background existing and proposed hydrologic data.
2. The proponent should provide plans outlining the following
   i. Existing and proposed plan and profile
   ii. Existing and proposed channel sections
   iii. Details for proposed typical channel sections
   iv. Sediment and erosion controls
   v. Staging plans
   vi. Seeding and landscaping plan (completed by a member of OALA in good standing)
   vii. Floodline delineation – existing and proposed
3. The proponent should document how the proposed natural channel design matches and/or enhances existing channel characteristics.
4. The proponent should document how the proposed channel will function within the watercourse block/valley system.
5. The proponent should document existing and proposed channel hydraulics, including stage/storage/discharge relationships.
6. The proponent should document potential impacts on both the existing terrestrial and fisheries conditions.
7. The proponent should provide a monitoring program outlining monitoring requirements for the various design disciplines.

9.0 Stormwater Management Facility Performance Monitoring

The following sections provide general language for the required SWM facilities monitoring program, which shall be written into the subdivision agreement as a separate schedule. The general language provided may need to be modified to include the site specific details for each facility. Where other LID facilities are proposed, the City, in consultation with the proponent, shall modify the text provided in the following sections to address the specific requirements of the facility being monitored.

9.1 General

The purpose of the monitoring program is to confirm to the satisfaction of the City of Pickering that the SWM facilities have been constructed and are functioning in accordance with the design specifications and the MECP Environmental Compliance Approval, prior to assumption.

Performance monitoring of the SWM facilities shall commence after 90% of the dwellings/lots have been constructed, graded and sodded within the facility’s catchment area. The facilities shall be monitored until:

(a) Two (2) years with the occurrence of four (4) significant rainfall events and two (2) wet rainfall events as defined below, or

(b) To a maximum of five (5) years with the occurrence of four (4) significant rainfall events and two (2) wet rainfall events as defined below.

A “significant rainfall event” is defined as an event where greater than 25 mm of rain has fallen in 4 hours. A “wet rainfall event” is defined as an event where greater than 15 mm of rain has fallen within the previous 24 hours between May and September.

A list of deficiencies, if any, and related data with respect to the SWM facilities will be required following each year of monitoring. The Owner is required to perform any remedial works identified by the monitoring program.

Any remedial works shall extend the period of the monitoring program, if necessary, until such time as the remedial works have been completed to the satisfaction of the City and have functioned to the specifications in the engineer’s design and the MECP Environmental Compliance Approval through 3 additional significant rainfall events.

9.2 SWM Pond

The intent of the monitoring program for the SWM Pond is to confirm to the satisfaction of the City of Pickering that the pond has been constructed and is functioning to the specifications in the engineer’s design and the MECP Environmental Compliance Approval with respect to the total suspended solids (TSS) removal efficiency and hydraulic function with respect to detention time and release rates.

Sediment Removal

1. After grading of the facility is completed and the SWM Pond liner (if applicable) has been installed, the Owner shall complete a topographic survey of the facility to determine the elevations prior to the facility being operational. The City requires that the survey work be completed in a dry condition. The Owner shall submit a plan to the City comparing the results of the topographic survey to the approved SWM Pond design. The results shall verify that the facility has been constructed in accordance with the approved design; otherwise the process may have to be repeated.

2. The forebay and main cell sediment levels shall be monitored until issuance of a Final Acceptance Certificate by the City. The Owner shall remove the sediments from the forebay on an annual basis, unless it has been demonstrated that the accumulated sediment volume is less than 25% of the forebay permanent pool volume. The volume of forebay sediments shall be estimated using at least 5 uniformly distributed measurements of sediment depth taken within the forebay. The Owner shall remove the sediments from the main cell when the accumulated sediment volume is greater than 25% of the main cell permanent pool volume. The volume of main cell sediments shall be estimated using at least 5 measurements of sediment depth along a mid section along the length of the facility. A secchi disk shall be used to estimate levels in a wet condition if the water level is too deep for a sediment rod to reach.

3. Prior to issuance of a Final Acceptance Certificate by the City, the Owner shall determine the sediment quality by taking samples of the sediment from both the forebay and main cell and submit them to an accredited lab; the results of these lab tests will indicate the disposal method and shall be submitted to the City. The Owner shall drain the facility and remove all sediments from the forebay and main cell in accordance with the *Environmental Protection Act* and MOE guidelines as determined by the test results. The Owner shall complete a second topographic survey after all the sediment has been removed. This topographic survey shall be submitted to the City, along with a comparative analysis to the survey taken after substantial completion and the approved SWM Pond design. The results shall verify that all sediments have been removed from the facility; otherwise the process may have to be repeated.

Water Quality Performance Monitoring

4. Water quality samplers shall be installed at the inlet and outlet of the SWM Pond to characterize the facility's removal efficiency for TSS. Flow-weighted water samples from the samplers at the inlet and outlet of the facility shall be collected after significant rainfall events and submitted to an accredited laboratory to test for TSS.

5. Water samples shall be taken for the period from substantial completion to the date on which a Final Acceptance Certificate is issued by the City. If it is found that the TSS removal efficiency is not meeting the SWM Pond's design objectives as per the MECP Environmental Compliance Approval then the City may require the Owner to undertake remedial works to the SWM Pond to ensure the facility is operating as designed, to the satisfaction of the City.

Water Quantity Performance Monitoring

6. A metric staff gauge shall be installed adjacent to the storm sewer inlet headwall so that the zero reading is set at the permanent pool elevation. The outlet structure shall be inspected on a monthly basis to ensure that perforated riser inlets are not blocked due to sediments or debris. The monthly inspection shall be undertaken in dry weather conditions, at least 120 hours after any rainfall event, as that is the expected drawdown time for the extended detention storage for the majority of SWM Ponds in Pickering. The monthly reports shall include a time-stamped picture of the staff gauge and a reading to determine any fluctuations in the permanent pool elevation.

7. Flow measurement equipment shall be installed at all inlets and outlets in addition to a water level sensor for the SWM Pond. Measurements from the monitoring equipment shall be made at 5 minute intervals. The water level sensor shall be referenced to a geodetic benchmark.

8. A tipping-bucket rain gauge shall be installed in a suitable location in the SWM Pond block (refer to guidance from meteorological organizations) which records rainfall data at 5 minute intervals. The rain gauge will need to be calibrated every spring during the monitoring period.

9. Data from the rain gauge shall be reviewed in conjunction with rainfall data from TRCA Rain Gauge 130 (if any issues use rainfall data from TRCA Rain Gauge 84 or 106) for four (4) significant rainfall events and two (2) wet rainfall events as defined below. The resulting data shall be analyzed to assess the following in comparison to the SWM Pond approved engineering design and the MECP Environmental Compliance Approval: permanent pool or normal water level; verification of the stage-discharge curve; fluctuation in water levels in response to rainfall events; and facility drain down time for a range of rainfall event sizes.

    - A "significant rainfall event" is defined as an event where greater than 25 mm of rain has fallen in 4 hours.

- A “wet rainfall event” is defined as an event where greater than 15 mm of rain has fallen within the previous 24 hours between May and September

10. If it is found that the SWM Pond is not meeting the design objectives stated above in (9) as per the MECP Environmental Compliance Approval then the Owner shall undertake remedial works, to the satisfaction of the City.

9.3 Bioswale

1. The Owner shall confirm the area connected to the Bioswale for the year in question, as it will change from year-to-year as the subdivision builds out and it may affect the quantity of runoff entering the system.

2. Flow measurement equipment shall be installed at the inlet and outlet of the bioswale. The monitoring equipment shall be installed immediately after substantial completion of the Bioswale facility.

3. Data from the rain gauge shall be reviewed in conjunction with rainfall data from TRCA Rain Gauge 130 (if there are any issues use rainfall data from TRCA Rain Gauge 84 or 106) for 20 rainfall events, including six (6) events as defined above, which represent erosive flows to ensure that these erosive flows are not occuring at a greater frequency than under existing conditions. The rainfall and flow measurements shall be processed in a graphical format to display the fluctuation over time.

4. If it is found that the Bioswale is not meeting the design objectives stated in (3) above, as per the MECP Environmental Compliance Approval, then the Owner shall undertake remedial works, to the satisfaction of the City.

9.4 Infiltration Trench

1. The Owner shall confirm the area connected to the Infiltration Trench for the year in question, as it will change from year-to-year as the subdivision builds out and it may affect the quantity of runoff entering the system.

2. The intent of the monitoring program is to determine the performance of the Infiltration Trench through completing a mass balance on the flow into the trench with the flow out of the trench measured at the overflow into the storm sewer system. The difference between these two measurements represents the volume of water that has infiltrated. Furthermore, the water level in the Infiltration Trench is being monitored to ensure that it drains within 72 hours and that the entire length of trench is being used for infiltration.

3. Flow measurement equipment shall be installed at the first manhole upstream of the Infiltration Trench to measure the inflow in addition to flow measurement equipment to measure the overflow into the storm sewer system. A series of piezometers may be installed along the length of the infiltration trench to monitor the water level and the infiltration rate and drawn down time of the facility. The elevation of piezometers shall be referenced to a geodetic benchmark. The monitoring equipment shall be installed immediately after substantial completion of the facility.

4. The data shall be reviewed in conjunction with rainfall data from the rain gauge. The rainfall and water level data for six (6) events, as defined above, shall be processed in a graphical format to display the fluctuation in water levels over time.

5. The resulting data shall be analyzed to assess the following in comparison to the approved engineering design: fluctuation in water levels in response to rainfall events throughout the entire trench length (to ensure the entire trench is being used prior to overflow); facility drain down time after rainfall events to ensure the facility has drained within the maximum length of time (72 hours); and number of overflows.

6. If the time to fully drain exceeds 72 hours, the Owner will be required to drain via pumping and clean out the perforated underdrain. If slow drainage persists, then the Owner shall undertake remedial works (consisting of removal and replacement of granular material and/or geotextile fabric), to the satisfaction of the City.

10.0 References

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11.0 Glossary of Terms

AMC (Antecedent Moisture Condition) - Represents the moisture content of soil based on recent precipitation. AMC I, AMC II and AMC III correspond to dry, average and wet antecedent moisture conditions. AMC I has the lowest runoff potential while AMC III has the highest. The curve number (CN) used to model runoff can be adjusted to account for variations from normal moisture conditions.

Bankfull Flow - Flow that corresponds to bankfull stage at which water just begins to enter onto the floodplain.

Baseflow - The portion of stream flow that is not due to storm runoff and is supported by groundwater seepage into a channel.

BMP (Best Management Practice) - State of the art methods or techniques used to manage the quantity and improve the quality of wet weather flow. BMPs include Source Controls, Conveyance Controls and End-of-Pipe Controls.

Catchbasin (CB) - Box like underground concrete structure with openings in curb and gutter designed to collect runoff from streets and pavement.

Conveyance Controls - A structural Best Management Practice that is located within the drainage system where flows are concentrated and are being conveyed along a corridor. Conveyance Controls include but are not limited to pervious pipes, roadside ditches, and other similar systems.

Curve Number (CN) - An index of runoff potential, ranging from 0 to 100, which can be determined based on land cover/use type, hydrologic soil group (or soil drainage), and antecedent moisture condition.

Directly Connected Impervious Area (XIMP) - The fraction of a drainage area that is impervious and drains directly to the gutter/storm sewer (i.e., impervious area that does not flow across pervious areas).

Drainage Area - The total surface area upstream of a point that drains toward that point. Not to be confused with watershed. The drainage area may include one or more watersheds.

Dual Drainage - Dual drainage is the system of stormwater conveyance that includes both a major and minor system (e.g., road and storm sewer).

Ecosystem - A biological community, including humans and their natural environment.

End of Pipe Controls - A structural Best Management Practice that is located at the end of a flow conveyance route. End-of-Pipe Controls on surface and below ground but are not limited to wet ponds, constructed wetlands and other similar systems.

Erosion - (1) The wearing away of the land surface by moving water, wind, ice or other geological agents, including such processes as gravitation creep; (2) Detachment and movement of soil or rock fragments by water, wind, ice or gravity (i.e., Accelerated, geological, gully, natural, rill, sheet, splash, or impact, etc.).

Erosion Control - Includes the protection of soil from dislocation by water, wind or other agents.

Evapotranspiration (ET) - The quantity of water transpired (given off), retained in plant tissues, and evaporated from plant tissues and surrounding soil surfaces. Quantitatively it is usually expressed in terms of depth of water per unit area during a specified period.

Extended Detention - A stormwater design features that provides for the gradual release of a volume of water in order to increase settling of pollutants and protect downstream channels from frequent storm events.

Fill - Fill means earth, sand, gravel, rubble, rubbish, garbage, or any other material whether similar to or different from any of the aforementioned materials, whether originating on the site or elsewhere, used or capable or being used to raise, lower, or in any way affect the contours of the ground. (O.R. 158).

Flood - A flow event that causes a river, lake, or other water bodies to rise above normal non-damaging limits.

Floodplain, Regulatory - The Regulatory floodplain is the approved standard used in a particular watershed to define the limit of the floodplain for regulatory purposes pursuant to Provincial Flood Plain Planning Policy Statement. The Regulatory floodplain is based on the regional storm, Hurricane Hazel, or the 100 year flood, whichever is greater.

Geomorphology - A branch of both physiography and geology that deals with the form of the earth, the general configuration of its surface, and the changes that take place due to erosion of the primary elements and the buildup of erosional debris.

Groundwater - The water below the surface, and typically below the groundwater table.

Hydraulic Grade Line (HGL) - The water level in a pipe as a result of the flow, pipe diameter, slope, roughness, downstream water levels, etc. HGL can be determined using the energy equation or with dual drainage computer models such as OTTSWMM or PCSWMM.

Hydrologic Cycle - Also called the water cycle, this is the process of water evaporating condensing, falling to the ground as precipitation and returning to the ocean as run-off.

IDF Data - Intensity Duration Frequency data is statistically derived from a rain gauge, and relates rainfall intensity and depth of rainfall to the return period and duration of a rainfall event.

Infiltration - The slow movement of water into or through a soil or drainage system.

Infiltration Rate - The rate at which stormwater percolates into the subsoil measured in depth per hour.

Irrigation - Human application of water to agricultural or recreational land for watering purposes.

Lot Level Controls - A practice or structural measure that is usually implemented at the beginning of a drainage system or at the lot level, to reduce the volume of runoff and minimize the concentration of pollution in overland flow from private property and prevent pollutants from entering Stormwater runoff or other environmental media, as described by the Ministry of the Environment.

Low Impact Development (LID) - A stormwater management strategy that makes use of best management practices (BMPs) to reduce impervious area associated with development, while using lot level and conveyance controls to store stormwater for infiltration, reuse, evaporation, etc. LID practices reduce runoff volume and improve water quality, reducing the requirements for downstream stormwater infrastructure. LID practices can include infiltration trenches, green roofs, permeable pavers, and many other methods.

Major System - The storm drainage system which carries the total runoff of the drainage system less the runoff carried by the Minor Drainage System (storm sewer). The Major Drainage System will function whether or not it has been planned and designed, and whether or not developments are situated wisely with respect to it. The Major Drainage System usually includes many features such as streets, gullies, and Major Drainage System channels.

Minor System - The storm drainage system which is frequently used for collecting, transporting, and disposing of snowmelt, miscellaneous minor flows, and storm runoff up to the capacity of the system. The capacity should be equal to the maximum rate of runoff to be expected from the minor design storm which may have a frequency of occurrence of one in 2, 5, or 10 years. The minor system may include many features ranging from curbs and gutters to storm sewer pipes and open drainage ways.

Oil/Grit Separator (OG/S) - Systems designed to remove trash, debris and some amount of sediment, oil and grease from stormwater runoff based on the principles of sedimentation for the grit and phase separation for the oil.

Outfall - The point, location, or structure where wastewater or drainage discharges from a sewer pipe, ditch or other conveyance to a receiving body of water.

Overland Flow Path - Open space floodway channels, road reserves, pavement expanses and other flow paths that convey flows typically in excess of the capacity of the Minor Drainage System.

Regional Storm - The current Regional storm in Pickering is Hurricane Hazel.

Regulatory Storm - The larger of the 100 year return period storm or the Regional storm.

Riparian Habitat - Riparian habitat is an area of transition between the aquatic ecosystem and the adjacent terrestrial ecosystem. It is located immediately landward of watercourses and other water bodies. Soils that exhibit signs of regular saturation and vegetation tolerant of periodic inundation characterize this zone. Riparian vegetation provides habitat, food and shelter and contributes to both the adjacent aquatic and terrestrial ecosystems.

Sediment - Soil, sand and minerals washed from land into water, usually after rain. They pile up in reservoirs, rivers and harbors, destroying fish-nesting areas and holes of water animals and cloud the water so that needed sunlight might not reach aquatic plans. Careless farming, mining and building activities will expose sediment materials, allowing them to be washed off the land after rainfalls.

Stability of Slope - Generally, a slope is stable if it is well vegetated and shows no signs of stress (e.g., tension cracks, localized sloughing, seepage, creep, etc.), or erosion and the ratio of forces resisting movement (shear strength, internal friction) over the active forces (gravity, seepage) is in excess of 1.5. Slope stability depends upon slope geometry, groundwater behavior, and the geotechnical properties of the bank materials. Other factors, such as river erosion, weathering, piping, fill placement and vegetation are significant in determining soil stability.

Subwatershed - The drainage area of one or more contributing watercourses to a river.

Subwatershed Plan - The result of a study undertaken within the drainage area of 1 or more Watercourses of a specific river following the guidance presented in the Ministry of the Environment Stormwater Management Planning and Design Manual.

Stormwater - Surface runoff, resulting from rain or snowmelt events.

Total Impervious Area (TIMP) - The fraction of a drainage area that is impervious (road, roof, driveway, etc.).

Uncontrolled Flow - The peak flow which has not been reduced through stormwater management controls.

Watercourse - A watercourse is flowing water, though not necessarily continuous, within a defined channel and with a bed or banks and usually discharges itself into some other watercourse or body of water.

Watershed - The drainage area of a river.

Watershed Plan - The result of a study undertaken within the drainage area of a specific river following the guidance presented in the Ministry of the Environment Stormwater Management Planning and Design Manual.

Wetland - A vegetated area such as a bog, fen, marsh, or swamp, where the soil or root zone is saturated for part of the year.

Sources

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Appendix A

- City of Pickering IDF Curve Parameters
- Design Storms
  - Chicago Storm Hyetograph (25 mm – 4 Hour)
  - AES 1 Hour and 12 Hour Storm Hyetographs (2 Year through 100 Year)
  - Hurricane Hazel Rainfall Hyetograph
  - Hurricane Hazel – Area Reduction
- CN Value Conversion Table (AMC I, II and III)

City of Pickering IDF Curve Parameters

Parameter	Return Period					
	2 Year	5 Year	10 Year	25 Year	50 Year	100 Year
A	715.076	1082.901	1313.979	1581.718	1828.009	2096.425
B	5.262	6.007	6.026	6.007	6.193	6.485
C	0.815	0.837	0.845	0.848	0.856	0.863

Notes:
Rainfall Intensity, I (mm/hr) = $A/(t+B)^C$, where t is time duration in minutes
IDF Data Source: Toronto City (1940-2007)

City of Pickering Rainfall Intensity

Rainfall Intensity (mm/hr)

Return Period	Duration (min)								
	5	*10*	*15*	*30*	*60*	*120*	*360*	*720*	*1440*
2 Year	109.2	76.1	61.7	39.1	23.8	14.0	5.7	3.4	1.9
5 Year	151.9	101.6	85.0	54.6	32.6	18.7	7.6	4.4	2.5
10 Year	180.1	118.5	100.5	64.9	38.5	21.8	8.9	5.1	2.8
25 Year	215.8	139.8	120.1	77.9	45.9	25.7	10.4	6.0	3.3
50 Year	242.3	155.7	134.6	87.5	51.4	28.7	11.6	6.6	3.6
100 Year	268.5	171.4	148.9	97.0	56.8	31.6	12.8	7.2	3.9

City of Pickering Rainfall Depth

Rainfall Depth (mm)

Return Period	Duration (min)								
	5	*10*	*15*	*30*	*60*	*120*	*360*	*720*	*1440*
2 Year	9.1	12.7	15.4	19.5	23.8	27.9	34.5	41.1	45.9
5 Year	12.7	16.9	21.3	27.3	32.6	37.4	45.8	53.2	59.0
10 Year	15.0	19.7	25.1	32.4	38.5	43.6	53.2	61.3	67.6
25 Year	18.0	23.3	30.0	38.9	45.9	51.5	62.7	71.4	78.5
50 Year	20.2	25.9	33.6	43.7	51.4	57.3	69.7	79.0	86.7
100 Year	22.4	28.6	37.2	48.5	56.8	63.1	76.6	86.5	94.7

City of Pickering 25mm 4-hr Chicago Storm Hyetograph

Time (min)	Intensity (mm/hr)
	25mm
0	0.00
10	2.17
20	2.38
30	2.66
40	3.03
50	3.58
60	4.47
70	6.20
80	12.18
90	41.67
100	15.28
110	9.22
120	6.88
130	5.62
140	4.80
150	4.21
160	3.78
170	3.45
180	3.18
190	2.95
200	2.76
210	2.62
220	2.47
230	2.35
240	2.23
Depth (mm)	**25.0**

City of Pickering AES Storm Hyetographs
2-yr Return Period

IDF Data: Toronto, Bloor St.
AES Distribution: Toronto

1-Hour AES Storm

Time (hr)	Precip. (mm/hr)
0	0.00
5	2.86
10	8.57
15	22.85
20	42.84
25	79.97
30	42.84
35	34.27
40	22.85
45	14.28
50	8.57
55	2.86
60	2.86
Depth (mm)	**23.8**

12-Hour AES Storm

Time (hr)	Precip. (mm/hr)
0	0.00
15	0.41
30	0.41
45	0.41
60	0.41
75	0.41
90	0.41
105	0.41
120	0.41
135	2.47
150	2.47
165	2.47
180	2.47
195	6.99
210	6.99
225	6.99
240	6.99
255	18.91
270	18.91
285	18.91
300	18.91
315	5.34
330	5.34
345	5.34
360	5.34
375	2.88
390	2.88
405	2.88
420	2.88
435	1.64
450	1.64
465	1.64
480	1.64
495	0.82
510	0.82
525	0.82
540	0.82
555	0.41
570	0.41
585	0.41
600	0.41
615	0.41
630	0.41
645	0.41
660	0.41
675	0.41
690	0.41
705	0.41
720	0.41
Depth (mm)	**41.1**

City of Pickering AES Storm Hyetographs
5-yr Return Period

IDF Data: Toronto, Bloor St.
AES Distribution: Toronto

1-Hour AES Storm

Time (hr)	Precip. (mm/hr)
0	0.00
5	3.91
10	11.74
15	31.30
20	58.68
25	109.54
30	58.68
35	46.94
40	31.30
45	19.56
50	11.74
55	3.91
60	3.91
Depth (mm)	**32.6**

12-Hour AES Storm

Time (hr)	Precip. (mm/hr)
0	0.00
15	0.53
30	0.53
45	0.53
60	0.53
75	0.53
90	0.53
105	0.53
120	0.53
135	3.19
150	3.19
165	3.19
180	3.19
195	9.04
210	9.04
225	9.04
240	9.04
255	24.47
270	24.47
285	24.47
300	24.47
315	6.92
330	6.92
345	6.92
360	6.92
375	3.72
390	3.72
405	3.72
420	3.72
435	2.13
450	2.13
465	2.13
480	2.13
495	1.06
510	1.06
525	1.06
540	1.06
555	0.53
570	0.53
585	0.53
600	0.53
615	0.53
630	0.53
645	0.53
660	0.53
675	0.53
690	0.53
705	0.53
720	0.53
Depth (mm)	**53.2**

City of Pickering AES Storm Hyetographs
10-yr Return Period

IDF Data: Toronto, Bloor St.
AES Distribution: Toronto

1-Hour AES Storm

Time (hr)	Precip. (mm/hr)
0	0.00
5	4.62
10	13.86
15	36.96
20	69.30
25	129.36
30	69.30
35	55.44
40	36.96
45	23.10
50	13.86
55	4.62
60	4.62
Depth (mm)	**38.5**

12-Hour AES Storm

Time (hr)	Precip. (mm/hr)
0	0.00
15	0.61
30	0.61
45	0.61
60	0.61
75	0.61
90	0.61
105	0.61
120	0.61
135	3.68
150	3.68
165	3.68
180	3.68
195	10.42
210	10.42
225	10.42
240	10.42
255	28.20
270	28.20
285	28.20
300	28.20
315	7.97
330	7.97
345	7.97
360	7.97
375	4.29
390	4.29
405	4.29
420	4.29
435	2.45
450	2.45
465	2.45
480	2.45
495	1.23
510	1.23
525	1.23
540	1.23
555	0.61
570	0.61
585	0.61
600	0.61
615	0.61
630	0.61
645	0.61
660	0.61
675	0.61
690	0.61
705	0.61
720	0.61
Depth (mm)	**61.3**

City of Pickering AES Storm Hyetographs
25-yr Return Period

IDF Data: Toronto, Bloor St.
AES Distribution: Toronto

1-Hour AES Storm

Time (hr)	Precip. (mm/hr)
0	0.00
5	5.51
10	16.52
15	44.06
20	82.62
25	154.22
30	82.62
35	66.10
40	44.06
45	27.54
50	16.52
55	5.51
60	5.51
Depth (mm)	**45.9**

12-Hour AES Storm

Time (hr)	Precip. (mm/hr)
0	0.00
15	0.71
30	0.71
45	0.71
60	0.71
75	0.71
90	0.71
105	0.71
120	0.71
135	4.28
150	4.28
165	4.28
180	4.28
195	12.14
210	12.14
225	12.14
240	12.14
255	32.84
270	32.84
285	32.84
300	32.84
315	9.28
330	9.28
345	9.28
360	9.28
375	5.00
390	5.00
405	5.00
420	5.00
435	2.86
450	2.86
465	2.86
480	2.86
495	1.43
510	1.43
525	1.43
540	1.43
555	0.71
570	0.71
585	0.71
600	0.71
615	0.71
630	0.71
645	0.71
660	0.71
675	0.71
690	0.71
705	0.71
720	0.71
Depth (mm)	**71.4**

City of Pickering AES Storm Hyetographs
50-yr Return Period

IDF Data: Toronto, Bloor St.
AES Distribution: Toronto

1-Hour AES Storm

Time (hr)	Precip. (mm/hr)
0	0.00
5	6.17
10	18.50
15	49.34
20	92.52
25	172.70
30	92.52
35	74.02
40	49.34
45	30.84
50	18.50
55	6.17
60	6.17
Depth (mm)	**51.4**

12-Hour AES Storm

Time (hr)	Precip. (mm/hr)
0	0.00
15	0.79
30	0.79
45	0.79
60	0.79
75	0.79
90	0.79
105	0.79
120	0.79
135	4.74
150	4.74
165	4.74
180	4.74
195	13.43
210	13.43
225	13.43
240	13.43
255	36.34
270	36.34
285	36.34
300	36.34
315	10.27
330	10.27
345	10.27
360	10.27
375	5.53
390	5.53
405	5.53
420	5.53
435	3.16
450	3.16
465	3.16
480	3.16
495	1.58
510	1.58
525	1.58
540	1.58
555	0.79
570	0.79
585	0.79
600	0.79
615	0.79
630	0.79
645	0.79
660	0.79
675	0.79
690	0.79
705	0.79
720	0.79
Depth (mm)	**79.0**

City of Pickering AES Storm Hyetographs
100-yr Return Period

IDF Data: Toronto, Bloor St.
AES Distribution: Toronto

1-Hour AES Storm

Time (hr)	Precip. (mm/hr)
0	0.00
5	6.82
10	20.45
15	54.53
20	102.24
25	190.85
30	102.24
35	81.79
40	54.53
45	34.08
50	20.45
55	6.82
60	6.82
Depth (mm)	**56.8**

12-Hour AES Storm

Time (hr)	Precip. (mm/hr)
0	0.00
15	0.86
30	0.86
45	0.86
60	0.86
75	0.86
90	0.86
105	0.86
120	0.86
135	5.19
150	5.19
165	5.19
180	5.19
195	14.71
210	14.71
225	14.71
240	14.71
255	39.79
270	39.79
285	39.79
300	39.79
315	11.24
330	11.24
345	11.24
360	11.24
375	6.06
390	6.06
405	6.06
420	6.06
435	3.46
450	3.46
465	3.46
480	3.46
495	1.73
510	1.73
525	1.73
540	1.73
555	0.86
570	0.86
585	0.86
600	0.86
615	0.86
630	0.86
645	0.86
660	0.86
675	0.86
690	0.86
705	0.86
720	0.86
Depth (mm)	**86.5**

Hurricane Hazel
Rainfall Hyetograph

Time (min)	Intensity (mm/hr)
0	0
60	6
120	4
180	6
240	13
300	17
360	13
420	23
480	13
540	13
600	53
660	38
720	13

Note: To be used with AMC III conditions

HURRICANE HAZEL RAINFALL DEPTHS

	Depth		Percent of
	mm	Inches	12 Hour
First 36 hours	73	2.90	-
37th hour	6	.25	3
38th hour	4	.17	2
39th hour	6	.25	3
40th hour	13	.50	6
41st hour	17	.66	8
42nd hour	13	.50	6
43rd hour	23	.91	11
44th hour	13	.50	6
45th hour	13	.50	6
46th hour	53	2.08	25
47th hour	38	1.49	18
48th hour	13	.50	6
	285	11.21	100

NOTE: For drainage areas 25 km^2 or less

HURRICANE HAZEL - AREAL REDUCTION

Drainage Area (km^2)	Percentage
0 to 25	100.0
26 to 45	99.2
46 to 65	98.2
66 to 90	97.1
91 to 115	96.3
116 to 140	95.4
141 to 165	94.8
166 to 195	94.2
196 to 220	93.5
221 to 245	92.7
246 to 270	92.0
271 to 450	89.4
451 to 575	86.7
576 to 700	84.0
701 to 850	82.4
851 to 1000	80.8
1001 to 1200	79.3
1201 to 1500	76.6
1501 to 1700	74.4
1701 to 2000	73.3
2001 to 2200	71.7
2201 to 2500	70.2
2501 to 2700	69.0
2701 to 4500	64.4
4501 to 6000	61.4
6001 to 7000	58.9
7001 to 8000	57.4

Source: Technical Guidelines for Flood Plain Management in Ontario, Working Paper C, Rainfall Analysis, Report to MNR, Dillon Consulting, August 1985

CN Value Conversion Table (AMC I, II, and III)

AMC II	AMC I	AMC III	AMC II	AMC I	AMC III
100	100	100	60	40	78
99	97	100	59	39	77
98	94	99	58	38	76
97	91	99	57	37	75
96	89	99	56	36	75
95	87	98	55	35	74
94	85	98	54	34	73
93	83	98	53	33	72
92	81	97	52	32	71
91	80	97	51	31	70
90	78	96	50	31	70
89	76	96	49	30	69
88	75	95	48	29	68
87	73	95	47	28	67
86	72	94	46	27	66
85	70	94	45	26	65
84	68	93	44	25	64
83	67	93	43	25	63
82	66	92	42	24	62
81	64	92	41	23	61
80	63	91	40	22	60
79	62	91	39	21	59
78	60	90	38	21	58
77	59	89	37	20	57
76	58	89	36	19	56
75	57	88	35	18	55
74	55	88	34	18	54
73	54	87	33	17	53
72	53	86	32	16	52
71	52	86	31	16	51
70	51	85	30	15	50
69	50	84			
68	48	84	25	12	43
67	47	83	20	9	37
66	46	82	15	6	30
65	45	82	10	4	22
64	44	81	5	2	13
63	43	80	0	0	0
62	42	79			
61	41	78			

Source: Mishra, Surendra and Vijay P. Singh (2003). Soil Conservation Service Curve Number (SCS-CN) Methodology. Norwell, MA: Kluwer Acedemic Publishers, p103.