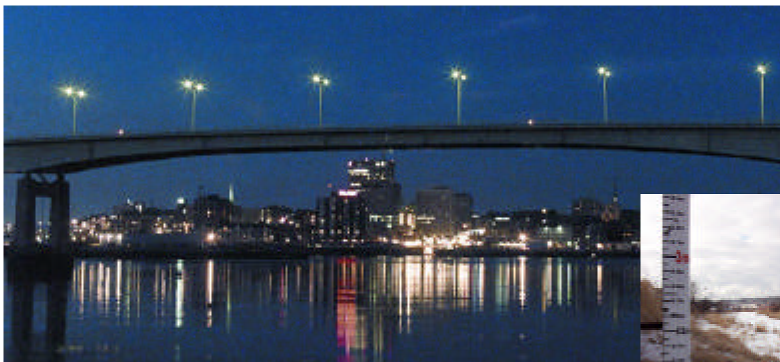

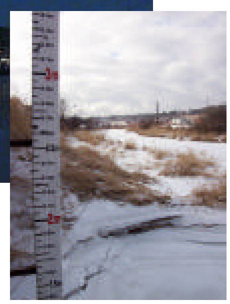

SAINT JOHN

City of Saint John

Storm Drainage Design Criteria Manual

September 9, 2008

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This document is not intended to eliminate the necessity for detailed design by a Professional Engineer, rather it is intended to standardize the materials, design criteria, and method of construction to be utilized in the installation of storm drainage systems.

The acceptance by the City of Saint John of the design of proposed storm drainage systems shall not relieve the Consultant of the responsibility for proper design, and hence the Consultant will retain full responsibility and liability for their design.

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1 DEFINITION OF TERMS

Approved or Approval: means approval by the Engineer unless otherwise stated. The Engineer's decision will be final and binding.

City: means the City of Saint John, a body corporate and includes the City's personal representatives or successors.

Consultant: means a consulting engineer or engineering firm who or which is currently licensed to practice within the Province of New Brunswick.

Developer: means the owner of the area of land proposed for development or subdivision, or their designated representative.

Development: means any erection, construction, addition, alteration, replacement, or relocation of or to any building or structure and any change or alteration in land use, buildings, structures, or surface cover.

Drainage Area:
(1) The area tributary to a single point of consideration, expressed in units of area. The drainage area may also be referred to as the catchment area, subcatchment area, watershed, subwatershed, drainage basin, or drainage subbasin.
(2) The area served by a drainage system receiving storm sewer discharge and surface water runoff.
(3) The area tributary to a watercourse.

Drainage Master Plan: means the compilation of data and mapping that delineates watersheds, indicates routes of the major and minor drainage systems, defines floodplains, indicates constraints associated with water quality and quantity, indicates erosion and bank stability problems, and indicates specific flood control and environmental objectives in the watershed.

Engineer: means the Chief City Engineer and any Engineer who is employed by the City and has been designated by the Chief City Engineer to act on his/her behalf.

Floodplain: means the relatively flat or lowland area adjacent to: a river, stream, watercourse, ocean, lake, or other body of water which has been, or may be, temporarily covered with floodwater during storms of specified frequency.

Hydrograph: means a graph showing the discharge of water with respect to time at a given point within a subwatershed.

Hyetograph: means a graph showing average rainfall, rainfall intensity, or rainfall volume with respect to time within a subwatershed.

Impervious: means a term applied to a material through which water cannot pass, or through which water passes with great difficulty over a prolonged duration of time.

Infiltration:
(1) The migration of water through the interstices or pores of a soil or other porous medium.
(2) The quantity of groundwater which enters into a sanitary sewerage system through cracks and defective joints.
(3) The entrance of water from the ground into a sewer or drain through breaks, defective joints, or porous walls.
(4) Absorption of liquid water by the soil, either as it falls as precipitation, or from a stream flowing over the surface.

<u>Intensity</u>: means the rate of precipitation derived from the quantity of precipitation expressed per unit of time.

<u>Major Storm</u>: means the storm used for design purposes of the Major Storm Drainage System – the runoff from which is used for design and sizing the major storm drainage system. The frequency of such a storm is 1 in 100 years (1% probability of being equalled or exceeded in any year).

<u>Major Storm Drainage System</u>: means the storm drainage system which water will follow in a major storm when the capacity of the minor system is exceeded. The major system usually includes features such as: streets, curb and gutter systems, swales, and major drainage channels. Minor storm drainage systems may reduce the flow in many parts of the major storm drainage system by storing and conveying water underground. Design of a major system is based on a storm frequency of 1 in 100 years.

<u>Minor Storm</u>: means the storm used for design purposes of the Minor Storm Drainage System – the runoff from which is used for design and sizing the minor storm drainage system. The frequency of such a storm is 1 in 5 years (20% probability of being equalled or exceeded in any year).

<u>Minor Storm Drainage System</u>: means the storm drainage system which is designed to eliminate or minimize inconveniences or disruption of activity as a result of runoff from the more frequent, less intense storms. The minor storm drainage system is sometimes termed the “convenience system” or “initial system”. The minor system may include many features ranging from curbs and gutters to storm sewer pipes and open drainage ways. Design of a minor system is based on a storm frequency of 1 in 5 years.

<u>NBDOE</u>: means the New Brunswick Department of Environment.

<u>NBDOT</u>: means the New Brunswick Department of Transportation.

<u>Overland Flow</u>: means the concentration and conveyance of stormwater runoff over the ground surface.

<u>Pervious</u>: means a term applied to a material through which water passes relatively freely over a short duration of time.

<u>Precipitation</u>: means any moisture that falls from the atmosphere including: snow, sleet, rain, and hail.

<u>Private Easement:</u> means a right given by a private citizen or private entity to another private citizen or private entity to make limited use of the private citizen’s or private entity’s property.

<u>Public Easement:</u> means a right given by a private citizen or private entity to the City of Saint John to make limited use of the private citizen’s or private entity’s property.

<u>Professional Engineer</u>: means a registered or licensed member, in good standing, of the Association of Professional Engineers and Geoscientists of New Brunswick.

<u>Runoff (Direct)</u>: means the total amount of surface runoff and subsurface storm runoff which reaches stream channels.

Storm Drainage System: means a system receiving, conveying, and controlling discharges in response to precipitation and snowmelt. Such systems consist of: ditches, culverts, swales, subsurface interceptor drains, roadways, curb and gutters, catchbasins, manholes, pipes, detention ponds, and service lateral lines.

Stormwater Runoff Storage: means the detention or retention of overland flow from a storm event allowing it to be released at a set rate during or after the storm event.

Detention Storage: means runoff that is detained during a storm and is released sometime after the peak of the storm has passed.

Depression Storage: means precipitation that is retained in small depressions and surface irregularities and does not become part of the stormwater runoff.

Storm Service Lateral: means a pipe that conveys water from the area surrounding the foundation to a point of discharge.

Stormwater Runoff: means the stormwater resulting from precipitation falling onto and running off of the surface of a subwatershed during and immediately following a period of rain, and/or snowmelt.

Subdivision: means the division of any area of land into two or more parcels, including a resubdivision, or a consolidation of two or more parcels.

Surcharge: means the flow condition occurring in closed conduits when the hydraulic grade line is above the conduit crown, or the transition from open channel flow to pressurised flow.

Time of Concentration: means the time required for stormwater runoff to concentrate and convey from the hydraulically most remote point of a subwatershed to the outlet or point under consideration. Time of concentration is not a constant, but varies with depth of flow, slope, and hydraulic condition of the subwatershed.

Trench Drainage Relief System: means a pipe system designed to collect groundwater from sewer main trenches and lower the hydraulic grade line of the groundwater below the invert of the sewer main.

Watercourse: means the full width and length including: the bed, banks, sides and shoreline, or any part, of a river, creek, stream, spring, brook, lake, pond, reservoir, canal, ditch or other natural or artificial channel open to the atmosphere, the primary function of which is the conveyance or containment of water whether the flow be continuous or not, in accordance with, “The Clean Water Act – Revised Statutes of New Brunswick”.

1.1 Purpose

This Storm Drainage Design Criteria Manual is intended to provide guidance and direction to Consultants and City of Saint John staff in relation to the design of storm drainage infrastructure within the City. Consultants and City staff shall complete their storm drainage designs in accordance with this Manual. This Manual shall apply, but not be limited, to: subdivisions of two parcels or greater; site design in support of building permit applications for multi-family residential, commercial, institutional, and industrial developments; and, design of storm drainage infrastructure to be owned and maintained by the City of Saint John.

2 STORM DRAINAGE SYSTEM

2.1 General

A storm drainage system is a system receiving, conveying, and controlling discharges in response to precipitation and snow melt. Such systems consist of: ditches, culverts, swales, subsurface interceptor drains, roadways, curb and gutters, catchbasins, manholes, pipes, detention ponds, and storm drainage service laterals. The Storm Drainage Design Criteria Manual illustrates the more common aspects encountered in the design of storm drainage systems.

All storm drainage systems within the City of Saint John shall be designed to achieve the following objectives:

- to prevent loss of life and to protect structures and property from damage due to flood events;
- to provide safe and convenient use of streets, lot areas, and other improvements during and following precipitation and snow melt events;
- to adequately convey stormwater runoff from upstream sources;
- to mitigate the adverse effects of stormwater runoff, such as flooding and erosion, on downstream properties;
- to preserve designated watercourses and natural designated wetlands; and
- to minimize the long-term effects of development on the receiving surface water and groundwater regimes from both a quantity and quality perspective.

In the City of Saint John, storm drainage systems are typically owned, operated, and maintained by either the City, the New Brunswick Department of Transportation, private landowners, or a combination of all three.

Complete documentation of all parameters relating to the design and construction of storm drainage systems is beyond the scope of this manual. This manual defines the parameters of greatest importance and presents the policies and accepted methods of the City.

The design of storm drainage systems, when submitted to the City, must bear the seal, signed and dated, of a Professional Engineer licensed, or registered to practice, with the Association of Professional Engineers and Geoscientists of New Brunswick.

This document is not intended to eliminate the necessity for detailed design by a Professional Engineer, rather it is intended to standardize the materials, design criteria, and method of construction to be utilized in the installation of storm drainage systems. Where, in the judgement of the Consultant, variations from this document are justified or required, and where the Consultant can show that alternate approaches can produce the desired results, such approaches will be considered for approval by the Engineer. In considering requests for variations from these design criteria, the Consultant shall take into consideration such factors as: safety, nuisance, system maintenance, operational costs, life cycle costs, environmental issues, and natural topography.

Designs will be accompanied by statements of certification by the Consultant to the effect that designs have been completed in accordance with these guidelines. Where the Consultant uses standards other than those outlined in this document, they shall clearly indicate in all appropriate documents and plans those areas of difference. The acceptance by the City of Saint John of the design of proposed storm drainage systems shall not relieve the Consultant of the responsibility for proper design, and hence the Consultant will retain full responsibility and liability for their design.

Like other municipal services, storm drainage systems must be carefully designed, reviewed, and approved prior to construction. In addition to these design criteria, all storm drainage systems shall conform to any requirements established by the New Brunswick Department of Environment (NBDOE). No system shall be constructed until the design has been reviewed and approved by the City and by NBDOE, as applicable.

Proposed storm drainage works must be based on sound engineering design. For stormwater design work, this often requires good quality hydrologic and hydraulic modeling. Stormwater modeling can be divided into two basic fields:

Hydrology, which is the study of runoff produced from rainfall and/or snowmelt, and the factors which influence it, and

Hydraulics, which is the study of water flow in the channels, pipes, streams, ponds, and rivers which convey it to the sea.

In each field, there are many techniques available for performing the required analysis. A qualified Professional Engineer is required to choose the best method for each situation.

2.2 Design Approach

2.2.1. Storm Drainage System Types

Developments shall be serviced by a dual drainage system consisting of both a minor storm drainage system (piped system) and a major storm drainage system (overland system).

2.2.2. Dual Storm Drainage System Design

The design of the dual storm drainage system, comprising the minor system and the major system, shall be carried out such that no proposed or existing structure be damaged by the runoff generated by any storm up to the 1 in 100 year return period storm. This requires proper care in the design of streets, curb and gutters, catchbasins, pipes, open channels, grading of lots and road profiles, setting of elevations or openings into buildings, foundation drains, roof drains, or other off-street connections.

In the event that the Consultant identifies an existing structure that may be negatively impacted by the runoff generated by any storm up to the 1 in 100 year return period storm, the Consultant shall notify the Engineer so that the situation may be reviewed and resolved to the satisfaction of the Engineer on an individual basis.

It is the responsibility of the Developer and/or Consultant to ensure that the proposed development does not create a downstream flooding problem, or aggravate an existing downstream flooding problem (refer to 2.2.5 for extent of analysis).

When adequate downstream capacity does not exist, one possible option is to upgrade downstream infrastructure. Alternatively, the Developer and/or Consultant may reduce peak flow through the use of storage, and a “zero-increase” covenant may be implemented that will limit post-development peak discharge to the existing pre-development peak discharge. In following this alternate approach, it is the responsibility of the Developer and/or Consultant to exercise innovative engineering design, including various methods of on-site storage, to mitigate the detrimental effects of their development by any storm up to the 1 in 100 year return period storm.

2.2.2.1. Minor Storm Drainage System

The minor storm drainage system shall be designed to convey stormwater runoff generated by the 1 in 5 year return period storm, thereby providing safe and convenient use of streets, lot areas, and other areas. The minor storm drainage system shall consist of: swales, subsurface interceptor drains, curb and gutters, culverts, catchbasins, manholes, pipes or conduits and service lateral lines in those areas where a piped storm drainage system is required.

2.2.2.2. Major Storm Drainage System

The major storm drainage system shall be designed to convey stormwater runoff generated by the 1 in 100 year return period storm, thereby preventing loss of life and protecting structures and property from damage. The capacity of the major storm drainage system shall be adequate to carry the discharge from a 1 in 100 year return period storm when the capacity of the minor storm drainage system is exceeded. The major storm drainage system shall consist of: ditches, open drainage channels, swales, roadways, detention ponds, culverts for watercourses, watercourses, floodplains, canals, ravines, gullies, springs, and creeks.

2.2.3. Travelled Way Drainage

For storms up to and including the 1 in 5 year return period storm, the drainage design shall provide for a travelled way of adequate width such that safe passage of all vehicles in both directions for all road classifications is maintained.

For storms up to and including the 1 in 100 year return period storm, the drainage design shall meet the requirement that the depth and spread of flow does not exceed the curb height and does not exceed the right-of-way width for residential streets and local collector streets.

In addition to the above criteria, for storm events up to and including the 1 in 100 year return period storm, the drainage design shall provide for a travelled way of adequate width such that safe passage of vehicles in both directions for major collector streets and arterial streets is maintained.

2.2.4. Storm Drainage System Outfall

The dual storm drainage system shall be extended to discharge to an existing downstream storm drainage system, or a watercourse.

2.2.5. Existing Storm Drainage System Outfall

The downstream storm drainage system shall have adequate capacity to capture and convey discharge from the proposed storm drainage system in addition to its own base flow rate of discharge. Any adverse impact, such as flooding or erosion as a result of the combined rate of discharge, on the downstream storm drainage system shall be investigated by the Consultant. Such investigation shall be carried out from the outfall location of the proposed storm drainage system to a location in the downstream system where the peak rate of discharge from the proposed storm drainage system is 10% of the combined peak rate of discharge in the downstream system.

The extent of any adverse impacts will be assessed by the Engineer based on this investigation. Depending upon the nature of any adverse impacts, the Engineer may require mitigative measures to be provided by the Consultant to the storm drainage system to prevent or alleviate such adverse impacts.

2.2.6. Basis of Design

Design of the storm drainage system shall be based on the state of development anticipated to exist for both the subwatershed under design and upstream subwatersheds when both areas are completely developed in accordance with the land-use zoning in place at the time of design.

2.2.7. Developed Areas

Except as indicated below in 2.2.8, design flows for residential, commercial, or industrial land uses (either existing or zoned as such for future development) shall be based on summer rainfall data and corresponding runoff coefficients for summer conditions.

2.2.8. Undeveloped Areas

When the area under design includes a significant proportion of undeveloped land (existing and zoned to remain undeveloped), peak design flows shall be the largest of flows estimated for both winter and summer conditions.

2.2.9. Long Duration

When the area under design requires calculation of flows for durations greater than 6 hours, design flows shall be the largest of the flows estimated for both winter and summer conditions.

2.2.10. Tailwater Conditions

Where the area under design includes an outfall to a watercourse or open ocean, consideration shall be given to the maximum tailwater condition occurring during peak flood level of the watercourse, maximum high tide, and/or storm surge. In addition, where discharge is directed to water bodies affected by sea level, 0.5 m shall be added to the tailwater elevation to recognize the effects of climate change.

2.2.11. Design Storm Duration

Selection of the 2-hour or 24-hour design storm shall consider the time of concentration and presence of storage facilities such that the storm duration is of sufficient length to examine the performance of the hydraulic structures in the watershed including storage facilities. In considering this issue, it may be appropriate to utilize design storms longer than 24 hours in duration.

2.3 Meteorological Data

Rainfall data is used in a variety of forms including intensity-duration-frequency curves, synthetic design storms, historical design storms, and historical long-term rainfall records. Selection of the proper form depends upon the type of computational procedure to be used, contingent upon the type of problem to be solved and the level of analysis required.

2.3.1. Rainfall Intensity – Duration – Frequency Curve

Appendix D contains rainfall intensity – duration – frequency curves which are based on annual rainfall at the Saint John Environment Canada weather station. Additional detailed historical rainfall information is available through the Atlantic Climate Centre of Environment Canada.

2.3.2. Synthetic Design Storm

Advanced procedures for the design of storm drainage systems requires the input of rainfall hyetographs, which specify rainfall intensities for successive time increments during a storm event. For this purpose, it is standard to use both synthetic and historical design storms hyetographs. Synthetic design storm hyetographs are intended to represent some of the long term statistical properties of recorded rainfall. The Chicago type distribution shall be used to derive synthetic design storm hyetographs from rainfall intensity - duration - frequency curves. Appendix D presents 2 hour and 24 hour duration Chicago type distributions for the 1 in 5 year, and 1 in 100 year return periods.

2.3.3. Historical Design Storm

In some instances the design of storm drainage systems requires the input of historical design storms for calibration of hydrologic and hydraulic models. Historical design storm hyetographs are intended to represent a specific recorded rainfall. Additional detailed historical rainfall information is available through the Atlantic Climate Centre of Environment Canada.

2.4 Runoff Methodology

There are numerous techniques and models the Consultant may use in the determination of stormwater runoff. Selection of an appropriate method must be based on an understanding of the principles and assumptions underlying the method and of the problem under consideration. It is, therefore, essential that appropriate techniques and models be selected and used by experienced engineers.

The following list of generally accepted runoff computational methods is provided by the City as a guide for the Consultant in selecting a runoff model. This listing is by no means to be considered as comprehensive or complete. Methods other than those listed below may be considered if their use is justified by the Consultant and approved by the Engineer.

Results may need to be verified by a second method, or calibration based on flow measurement.

2.4.1. The Rational Method

The Rational Method is the most widely used empirical equation for predicting instantaneous peak discharge from a small subwatershed. The peak discharge is assumed to occur at a rainfall duration equal to the time of concentration. The Rational Method may be used for the determination of instantaneous peak runoff in the design of storm drainage systems up to 20 hectares in area, for preliminary design of systems serving larger areas, and as a check on flows determined by other methods. This method should not be used to determine the size or hydraulic performance of stormwater storage facilities.

2.4.2. The USSCS Method

Methods described in the United States Soil Conservation Service (USSCS) Technical Report No. 20 and No. 55 may be used to determine peak flow and volume for rural areas, to determine urbanization impacts, and to evaluate the performance of storage facilities.

2.4.3. SWMM and OTTSWMM

The United States Environmental Protection Agency (USEPA), Storm Water Management Model (SWMM), and the University of Ottawa Storm Water Management Model (OTTSWMM) may be used for design of piped systems and to model overland flow in a major system.

2.4.4. HYMO and OTTHYMO

The Hydrologic Model (HYMO) and the University of Ottawa Hydrologic Model (OTTHYMO) may be used for the development of storm drainage master plans, and in the analysis of stormwater management proposals for new development. The model includes capability for storage calculations and stream channel routing.

2.4.5. HEC

The United States Army Corps of Engineers (USACE) Hydrologic Engineering Center (HEC) model may be used for modeling overland storm drainage systems, watercourses and determining the extent of floodplains.

2.5 Hydrologic Design Criteria

2.5.1. Rational Method

2.5.1.1. Runoff Coefficients

Tables 2.1 and 2.2 respectively present Rational Method runoff coefficients appropriate for various land uses and surface types. Selection of values from Tables 2.1 and 2.2 shall be based on permeability of the surface, lot size, soil conditions, and other relevant considerations. For residential, commercial or industrial land uses, rainfall intensities from Figure D.1 (Appendix D) shall be used with coefficients for summer ground conditions, unless use of winter conditions is justified by Section 2.2.9.

Where runoff from an area that includes a significant proportion of undeveloped land is to be determined, a comparison shall be made between summer and winter ground conditions using winter runoff coefficients from Table 2.3 and winter rainfall intensities from Figure D.6 (Appendix D) accounting for snowmelt contributions. For winter or year-round runoff calculations, the coefficients from Tables 2.1, 2.2, and 2.3 shall be increased according to Table 2.4 for the 1 in 100 year return period.

Table 2.1 Rational Method Runoff Coefficients for Various Areas for Summer Conditions

Character of Area	Description of Area	Runoff Coefficient
Industrial	Light	0.50 to 0.80
	Heavy	0.60 to 0.90
Commercial	Downtown	0.70 to 0.95
	Neighbourhood	0.50 to 0.70
Residential	Single-Family	0.30 to 0.50
	Detached Multi-Unit	0.40 to 0.60
	Attached Multi-Unit	0.60 to 0.75
	Suburban, Unserviced	0.25 to 0.40
	Apartment	0.50 to 0.70
Other	Park, Cemetery	0.10 to 0.25
	Playground	0.20 to 0.40
	Railroad Yard	0.20 to 0.40
	Unimproved/Vacant Lands	0.10 to 0.30

Table 2.2 Rational Method Runoff Coefficients for Various Surfaces for Summer Conditions

Character of Surface	Description of Surface	Runoff Coefficient
Impervious	Asphalt	0.70 to 0.95
	Concrete	0.80 to 0.95
	Brick	0.70 to 0.85
	Rooftop	0.75 to 0.95
Pervious	Lawn, Sandy Soil, < 2%	0.05 to 0.10
	Lawn, Sandy Soil, 2%-7%	0.10 to 0.15
	Lawn, Sandy Soil, > 7%	0.15 to 0.20
	Lawn, Clayey Soil, <2%	0.13 to 0.17
	Lawn, Clayey Soil, 2%-7%	0.18 to 0.22
	Lawn, Clayey Soil, >7%	0.25 to 0.35

Note: Higher values than those presented in Tables 2.1 and 2.2 are required to account for steeply sloped areas, longer duration events, and longer return periods to account for decreased infiltration and other losses.

Table 2.3 Rational Method Runoff Coefficients for Winter Conditions		
Character of Area/Surface	**Return Period**	**Runoff Coefficient**
All areas/surfaces with Summer coefficient < 0.80	5 year	0.80
All areas/surfaces with Summer coefficient < 0.80	100 year	1.00

Table 2.4 Rational Method Runoff Coefficients for the 100 Year Return Period	
Runoff Coefficient for 5 to 10 Year Return Period	**Corresponding Runoff Coefficient for 100 Year Return Period**
0.10	0.20
0.20	0.35
0.30	0.50
0.40	0.65
0.50	0.80
0.60	0.90
0.70 to 1.00	1.00

2.5.1.2. Winter Runoff

Where calculation of winter runoff is required, frozen ground shall be simulated by assuming the area to be 80% paved in a 1 in 5 year design storm and 100% paved in a 1 in 100 year design storm. Winter rainfall intensities from Figure D.6 (Appendix D) shall be used for calculating winter runoff.

2.5.1.3. Snowmelt

Estimation of snowmelt contribution is a complex process dependent on a number of variables, often not published for a given region. In lieu of available data, estimated snowmelt of 1.5 mm per hour shall be added to winter rainfall intensity.

2.5.1.4. Time of Concentration

Time of concentration (T_c) for a storm drainage system shall include both inlet time (T_i) and the travel time (T_t) to the point at which peak flow is to be estimated. Travel time (T_t) and time of concentration (T_c) for overland flow may be estimated by methods described by the United States Soil Conservation Service (USSCS) presented in Appendix B. For most piped systems in medium density urban areas, it is expected that a minimum 5 minute inlet time (T_i) will be used. Travel times (T_t) in piped systems shall be based on velocities at peak design flow.

2.5.2. United States Soil Conservation Service (USSCS) Method

2.5.2.1. Hydrologic Soil Group (HSG)

The USSCS Method categorizes soils into one of four hydrologic soil groups (HSG) contingent upon its surface infiltration rate, and subsurface permeability rate. Table 2.5 presents USSCS Method hydrologic soil groups.

Table 2.5 USSCS Method Hydrologic Soil Group (HSG) Classification	
USSCS Method Hydrologic Soil Group (HSG)	**Description**
A	• Very low runoff potential • Very high infiltration rate (consistent with well drained sand and gravel)
B	• Moderate runoff potential • Moderate infiltration rate (consistent with silt and sand)
C	• High runoff potential • Low infiltration rate (consistent with clay and silt)
D	• Very high runoff potential • Very low infiltration rate (consistent with saturated clays and high water tables)

2.5.2.2. USSCS Method Curve Numbers

Table 2.6 presents USSCS Method curve numbers for various land uses and hydrologic conditions. Selection of values from Table 2.6 shall be based on permeability of surface or % impervious area, lot size, soil condition, and other relevant considerations. For ordinary residential, industrial, or commercial land uses, rainfall data from Figure D.2 through Figure D.5 (Appendix D) shall be used with curve numbers for summer ground conditions unless otherwise justified by Section 2.2.9. Where runoff from an area that includes a significant portion of undeveloped land is to be determined, a comparison shall be made between summer and winter ground conditions using curve numbers to account for frozen ground, and rainfall data from Figure D.2 through Figure D.5 accounting for snowmelt contribution.

Table 2.6 USSCS Method Curve Numbers						
Character of Area	**Hydrologic Condition**	**Average Impervious Area**	**USSCS Method Curve Numbers For Hydrologic Soil Group**			
		(%)	**A**	**B**	**C**	**D**
Pervious Areas (Open Space, Lawn, Park)	Poor (grass cover <50%)		68	79	86	89
	Fair (grass cover 50%-75%)		49	69	79	84
	Good (grass cover > 75%)		39	61	74	80
Impervious Areas			98	98	98	98
Roadways	Paved with curb and gutter		98	98	98	98
	Paved with open ditch		83	89	92	93
	Gravel with open ditch		76	85	89	91
	Dirt with open ditch		72	82	87	89
Industrial		72	81	88	91	93
Commercial		85	89	92	94	95
Residential	1/8 Acre or Less	65	77	85	90	92
	1/4 Acre	38	61	75	83	87
	1/3 Acre	30	57	72	81	86
	1/2 Acre	25	54	70	80	85
	1 Acre	20	51	68	79	84
	2 Acre	12	46	65	77	82
Newly Graded	No Vegetation		77	86	91	94
Meadow	Good (grass cover > 75%)		30	58	71	78
Woods	Poor (grazed and burned)		45	66	77	83
	Fair (grazed not burned)		36	60	73	79
	Good (not grazed or burned)		25	55	70	77
Farmsteads			59	74	82	86

2.6 <u>Minor Storm Drainage System</u>

2.6.1. <u>Design Requirements</u>

Minor storm drainage systems shall be designed to convey, without surcharge, the runoff resulting from the 1 in 5 year return period storm.

As a preliminary check on the capacity of a piped storm system, the Manning's equation can be used. This will be particularly useful for initial sizing of the pipes. However, a more detailed analysis of the system as a whole will be required.

Analysis of the capacity of a proposed or existing storm sewer system will determine the hydraulic grade line (HGL) when the storm system is conveying the 1 in 5 year flows, and will take into account losses at manholes and other junctions, the headloss through the pipes, and any backwater conditions at the outlet of the storm sewer system.

To ensure that the minor storm drainage system is not subjected to flows greater than its design capacity, it is required that the Consultant check the total inlet capacity for the entire system. It is likely that this analysis will determine that during a major storm, flows greater than a 1 in 5 year return period storm will enter the storm sewer system, and the Consultant will likely need to specify inlet control devices (ICDs) to limit the quantity of stormwater runoff that enters the minor storm drainage system. To streamline the design process, the Consultant may calculate the 1 in 5 year flows to each catchbasin using the appropriate hydrologic methods, specify an inlet control device for each catchbasin which limits the flow to approximately the design flow for the 1 in 5 year storm, and then calculate the hydraulic grade line. Contingent upon the results of hydraulic grade line analysis, it may be necessary to revise some of the junctions, or revise some of the storm sewer main diameters to ensure that the hydraulic grade line is contained within the pipe.

2.6.2. Minimum Velocity

Under peak design flow (PDF) conditions from the tributary area, when fully developed, stormwater flow velocities in pipes must be a minimum of 0.6 m/s to maintain self-cleansing of the pipes.

2.6.3. Maximum Velocity

Under peak design flow (PDF) conditions from the tributary area, when fully developed, stormwater flow velocities in pipes must not exceed a maximum of 6.0 m/s to reduce the potential for scour.

2.6.4. Minimum Diameter

Storm sewer main diameters shall not be less than 300 mm.

Catchbasin lateral diameters shall not be less than 200 mm.

2.6.5. Changes in Diameter

Storm sewer main diameters must not decrease in the downstream direction. The exception is an inlet pipe being oversized to overcome the effects of inlet control.

2.6.6. Minimum Slope

The minimum pipe slope for storm sewer mains shall be 0.4%. The minimum slope for storm sewer mains on a permanent dead-end shall be 0.6%. Under special conditions, and upon approval from the Engineer, slopes less than 0.4% (mains) and 0.6% (dead-ends) may be permitted provided that self-cleansing velocities under full flow conditions are maintained. Minimum pipe slope for catchbasin laterals shall be 1.0%.

2.6.7. Minimum Depth

The depth of storm sewer mains, measured from the design grade of the final surface to the top of the pipe, must be a minimum of 1.2 m. Catchbasin laterals shall have a minimum depth of cover of 0.9 m.

2.6.8. Maximum Depth

The depth of storm sewer mains, measured from the design grade of the final surface to the top of the pipe must not exceed a maximum of 6.0 m. Under special conditions, and upon approval from the Engineer, the maximum depth of storm sewer mains may be increased such that the depth to the top of the pipe at any manhole location shall not exceed 8.0 m.

2.6.9. Location

All storm sewer mains, outfalls, and appurtenances shall be located within the street right-of-way or an easement for municipal services owned by the City of Saint John.

Easements for municipal services shall be of sufficient width to allow safe access to the pipe line in accordance with the requirements of the Occupational Health and Safety Act for the Province of New Brunswick. The minimum width of an easement for municipal services shall be 6.0 m. However, the actual width shall depend upon the depth and size of any pipe contained therein such that safe access to the pipe is possible, and upon the direction of the Engineer.

Depending upon the length and location of the easement for municipal services, the City may require a service road to be provided within the easement for municipal services for access and maintenance purposes.

Where master planning indicates a need to accommodate future upstream lands naturally tributary to the drainage area, an easement for municipal services shall be provided by the Developer from the edge of the street right-of-way to the upstream limit of the subdivision.

2.6.10. Manholes

A manhole must be provided on a storm sewer main at any change in diameter, material, horizontal alignment, vertical alignment, pipe main junctions, and where a catchbasin is to be connected to a storm sewer main.

Where a storm sewer main diameter is less than 1,500 mm, manhole spacing shall not exceed 120 m. Where a storm sewer main diameter is equal to or greater than 1,500 mm, manhole spacing will be determined in consultation with the Engineer.

The following criteria shall be used for pipe elevation and alignment in storm drainage manholes to account for energy losses through the manhole:

- An invert drop equal to the difference in pipe diameter shall be provided unless otherwise determined by appropriate hydraulic calculations;
- The crown of a downstream pipe shall not be higher than the crown of an upstream pipe;
- An internal drop manhole shall be constructed where the vertical drop between pipe inverts in the manhole exceeds 1.0 m;
- The Consultant shall take into consideration energy losses at manholes during peak flow conditions to ensure that surcharging of the system does not occur;
- The minimum internal diameter of a manhole shall be 1,050 mm. The consultant shall ensure that the internal diameter is adequate to accommodate all pipe and appurtenances in accordance with manufacturer’s recommendations; and
- Tee base manholes may be used for storm pipe sizes of 900 mm diameter and larger.

Manhole ladders are not permitted.

2.6.11. Storm Drainage Service Laterals

All storm drainage service laterals shall be installed according to the following provisions:

- For single-family lots, one storm drainage service lateral is to be supplied to each existing lot or potential future lot which could be created under the zoning in effect at the time of approval;
- For semi-detached lots, one storm drainage service lateral is required;

- For single-family and semi-detached lots, storm drainage service laterals shall be a minimum diameter of 100 mm. Storm drainage service laterals for other forms of development shall be sized in accordance with the design flow;
- The storm drainage lateral shall be laid at a minimum grade of 1% to the limit of the street right-of-way.

2.6.12. Groundwater Migration

The Consultant shall assess the possibility of groundwater migration through mainline, lateral, and service lateral trenches resulting from the use of pervious bedding material. Corrective measures, including provision of impermeable collars or plugs, to reduce the potential for basement flooding or undermining by erosion resulting from groundwater migration shall be employed.

2.6.13. Foundation Drains

Foundation drains will normally be connected by gravity to the minor storm drainage system unless the Consultant determines that surcharging of the system in a 1 in 100 year design storm will result in basement flooding or foundation damage. The invert elevation of the lateral at the limit of the street right-of-way shall be established at least 300 mm above the elevation of the obvert of the storm sewer main at the point of connection.

Where a minor storm drainage system does not exist, other options may be permitted as specified in the National Building Code of Canada, latest edition, Division B, Part 9.14 – Drainage.

Foundation drains shall not be permitted to discharge to the ground surface in such a way as to direct stormwater runoff to the street surface, walkways, or adjacent private property.

Storm drainage service laterals shall not be connected to sanitary sewer service laterals or mains.

2.6.14. Roof Drains

For residential developments, roof drains shall not be connected to storm drains, but shall discharge onto splash pads at the ground surface a minimum of 600 mm from the foundation wall in a manner that will carry water away from the foundation wall.

For developments other than residential, roof drains may be directly connected to the piped storm drainage system provided the Consultant confirms sufficient capacity exists.

2.6.15. Catchbasins

Catchbasins shall be installed at the curb of the street and shall be adequately spaced to prevent excessive water from flowing in the travelled lanes during storm events corresponding to the design of the minor system. The maximum distance for curb flow prior to being intercepted by a catchbasin shall be 120 m.

At intersections, catchbasin locations shall be dependent upon the slopes of intersecting streets and the alignment of the intersection.

It is vital that the interception capacity of the system of catchbasins be compatible with the design capacity of the storm drainage system. While the storm drainage mains will be designed for open channel flow conditions for the 1 in 5 year return period storm, the actual flows captured by the catchbasins during the 1 in 100 year return period storm shall be determined.

In areas where there is a potential for contamination of stormwater (eg. near service stations), the Engineer may require inverted siphons in catchbasins or other specialized stormwater treatment units.

All catchbasin laterals shall be connected to the manhole with an invert 1 m above the invert of the outgoing pipe. In cases where the diameter of the outgoing pipe is greater than 1 m, catchbasin laterals shall be connected to the manhole such that the invert of the catchbasin lateral is at the same elevation as the obvert of the outgoing pipe.

Catchbasin laterals shall not protrude into the catchbasin or manhole by more than 150 mm and shall be grouted with an approved non-shrink grout and finished on the inside and outside of the structure.

Catchbasin to catchbasin connections are not permitted, unless approved by Engineer.

2.6.16. Inlet Control Devices

Inlet control devices (ICDs) must be provided where there is risk of surcharging the minor storm drainage system by storm events that exceed the 1 in 5 year return period. Typical ICD sizing requirements for medium density residential development are provided in Table 2.7. Detailed ICD sizing requirements and theory are provided in Appendix C.

Where ICDs are specified in catchbasins, prefabricated ICDs can be used. Alternatively, they can be installed by cutting and grouting the lateral sufficiently inside the catchbasin to allow the placement of a cap on the end of the lateral with the appropriate size orifice to control the flows.

Table 2.7 Typical Inlet Control Device (ICD) Sizes

Catchbasin Tributary Area (ha)	ICD Limiting Flow (L/s)	ICD Diameter (mm)
0.1	16	85
0.2	32	120
0.3	48	150
0.4	64	170

Note: Based on a Rational Method runoff coefficient (C = 0.50)
for medium density residential development, inlet time (T_i = 5 min)
head on catchbasin lateral of 1.13 m measured from center of orifice to gutter grade.

2.6.17. Inlets

Inlets to piped storm drainage systems shall require grates to prevent entry for pipes 375 mm in diameter or larger. The orientation of the bars on the grate shall be vertical. The design of the inlet shall take into consideration the effect of the grating on restriction of flow into the pipe. Refer to Section 2.8.9 for grate design requirements.

2.6.18. Outfalls

Design of outfalls from piped storm drainage systems into any receiving body of water shall take into consideration such factors as normal water level, public safety, erosion control and aesthetics.

Outfalls from piped storm drainage systems of 375 mm in diameter and larger shall require grates to prevent entry, unless otherwise directed by the Engineer. The orientation of the bars on the grate shall be horizontal. The design of the outfall shall take into consideration the effect of the grating on restriction of flow out of the pipe. Inverts of outfall pipes shall be installed above the normal winter ice level in the receiving stream, wherever possible. Refer to Section 2.8.9 for grate design requirements.

2.6.19. Required Pipe Strength

All pipe installed within the street right-of-way, or in an easement for municipal services, shall be as specified in the *City of Saint John General Specifications, latest revision.*

Required pipe strength shall be determined using the Marston and Spangler equations, or by nomograph method as published by the American Concrete Pipe Association for reinforced concrete pipe or the Uni-Bell PVC Pipe Association for PVC pipe.

2.6.20. Separation of Total Suspended Solids (TSS)

For multi-family residential, institutional, industrial, and commercial buildings, and for subdivisions where the Engineer deems necessary, stormwater treatment systems capable of meeting or exceeding the following performance criteria shall be required:

.1 80% of total suspended solids (TSS) to be removed and contained for all rainfall events producing peak runoff up to and including 20% of the 2-year rainfall event based on local meteorological rainfall data.

2. 80% of total suspended solids (TSS) to be removed and contained for the total average annual precipitation based on local meteorological data.

For uniformity in benchmarking different technologies, TSS removal is to be based on the following Environmental Protection Agency (EPA) standard particle size distribution (PSD):

Particle Size (μm)	**Particle Type**	**US EPA (% by mass)**
<20	medium silt/coarse silt	20
20 to 60	coarse silt/fine sand	20
60 to 130	fine sand	20
130 to 400	medium sand	20
400 to 4000	coarse gravel/fine sand	20

The specific gravity to be used for unit sizing purposes is 2.65 for all particle sizes.

The selected manufacturer of stormwater treatment systems shall submit design drawings and calculations to the Consultant for review and approval. In addition, the manufacturer shall provide written certification by a registered Professional Engineer of the unit's projected performance for the specific project.

2.7 Major Storm Drainage System

2.7.1. Minor Storms

In storms corresponding to the basis of design for the minor drainage system, it is expected that roadways will remain free of water other than that amount accumulated between inlets.

2.7.2. Major Storms

For barrier-type curb applications, storm drainage design shall provide that the depth and spread of flow in a 1 in 100 year return period storm shall be contained within the right-of-way.

For mountable-type curb applications, the area located directly behind the curb must be graded in order that there be no overflow discharged from the right-of-way except at easements for municipal services designed to convey the overland flow.

All low points in the roadway profile must be designed to collect and convey stormwater runoff off the roadway via a drainage easement designed to convey the overland flow.

Provision shall be made to remove runoff into drainage channels, watercourses, and pipe systems at low points and at intervals such that this criteria is achieved.

2.7.3. Off-Street Drainage

In order to avoid seepage and winter icing problems on the street caused by groundwater seeping over the top of the curb, the Consultant shall provide a perforated curb drainage system, where required. Concentrated surface flows reaching the street right-of-way shall be directed to a pipe inlet.

Catchbasins shall be installed at locations where flow over the curb creates winter icing . Area catchbasins with pyramid grates shall be installed in off-street locations where concentrated flow would otherwise cross a sidewalk or walkway.

2.7.4. Ditches and Open Channels

Roadway ditches, where curb and gutter systems are not required, shall be designed to conform to the typical cross section for rural roads as detailed in the *City of Saint John General Specifications, latest revision*. Ditches shall be designed with adequate capacity to carry the flow expected from the 1 in 100 year return period storm.

Ditches shall have a minimum longitudinal grade of 1% unless otherwise approved by the Engineer.

2.7.5. Maximum Velocity

To minimize erosion, maximum permissible velocities in ditches or open channels that convey stormwater runoff shall not exceed values set forth in Table 2.8 in a 1 in 100 year return period storm unless the channel is lined or acceptable energy dissipation facilities are provided.

Table 2.8 Maximum Permissible Mean Channel Velocity

Channel Material	**Maximum Permissible Mean Channel Velocity (m/s)**
Fine Sand	0.45
Coarse Sand	0.75
Fine Gravel	1.85
Earth – Sandy Silt	0.60
Earth – Silty Clay	1.05
Earth – Clay	1.20
Bermuda Grass Lined – Earth – Sandy Silt	1.85
Bermuda Grass Lined – Earth – Silty Clay	2.45
Kentucky Blue Grass Lined – Earth – Sandy Silt	1.50
Kentucky Blue Grass Lined – Earth – Silty Clay	2.15
Sedimentary Bedrock – Poor	3.05
Sedimentary Bedrock – Sandstone	2.45
Sedimentary Bedrock – Shale	1.05
Igneous Bedrock	6.10
Metamorphic Bedrock	6.10

2.8 Culverts

2.8.1. Minimum Diameter

Minimum culvert diameters shall be 450 mm for circular culverts. Minimum culvert width by height is 450 mm x 450 mm for rectangular culverts. No downstream decrease in culvert sizing shall be permitted except to improve inlet hydraulics.

2.8.2. Minimum Depth

Minimum cover for culverts under roadways is to be in accordance with manufacturer's specifications.

2.8.3. Maximum Depth

In areas of excessive depth of bury, the Engineer may require the Consultant to submit pipe strength calculations including earth loading, line loading, and induced loading, accounting for site conditions and construction practices.

2.8.4. Hydraulic Capacity

Culverts are to be sized to convey instantaneous peak flows with a headwater depth (*HW*) to culvert diameter (*D*) ratio of 1.0 accounting for both inlet control and outlet control.

Culverts located under driveways and roadways are to be designed to accommodate the 1 in 5 year return period storm, unless otherwise directed by the Engineer.

Culverts located in watercourses are to be designed to accommodate the 1 in 100 year return period storm, unless otherwise directed by the Engineer.

2.8.5. Maximum Headwater Depth

Maximum headwater elevation (*HW*) for both inlet control and outlet control shall be reviewed by the Consultant relative to adjacent ground surface and adjacent structures for compatibility. The Consultant may reduce maximum headwater elevations (*HW*) for culverts under inlet control by improving inlet hydraulics. Table 2.9 and Table 2.10 present entrance loss coefficients (k_e) for reinforced concrete pipe (RCP) and corrugated steel pipe (CSP).

Table 2.9 Entrance Loss Coefficients (k_e) for Reinforced Concrete Pipe (RCP) Culverts Under Inlet Control

Inlet Geometry	Entrance Loss Coefficient (k_e)
Projecting from fill (bell end)	0.2
Projecting from fill (square cut end)	0.5
Mitered to conform to slope	0.7
Headwall or headwall and wingwalls (bell end)	0.2
Headwall or headwall and wingwalls (square cut end)	0.5
Flared inlet conforming to slope	0.5
Headwall or headwall and wingwalls (rounded edge)	0.1

Table 2.10 Entrance Loss Coefficients (k_e) for Corrugated Steel Pipe (CSP) Culverts Under Inlet Control	
Inlet Geometry	**Entrance Loss Coefficient (k_e)**
Projecting from fill	0.9
Mitered to conform to slope	0.7
Headwall or headwall and wingwalls (square edge)	0.5
Flared inlet conforming to slope	0.5
Headwall or headwall and wingwalls (rounded edge)	0.2
Bevelled ring	0.25

2.8.6. Inlet Design

An approved inlet headwall, or some other acceptable form of embankment stabilization and erosion control is required for all culverts under roadways.

2.8.7. Outlet Design

An approved outlet headwall, or some other acceptable form of embankment stabilization and erosion control is required for all culverts under roadways.

2.8.8. Outlet Velocity

The maximum culvert outlet velocity shall be 4.0 m/s. A riprap splash pad and apron must be designed by the Consultant to transition the culvert outlet velocity to the mean downstream channel velocity. Riprap shall be sized in accordance with Equation 2.2.

$$D_{mean} = 0.019 \cdot V^2 \qquad [2.2]$$

where:

D_{mean} = equivalent spherical diameter of riprap (m)
V = culvert outlet velocity (m/s)

Culvert outlet velocities must not exceed the maximum permissible mean channel velocities for a given channel material as presented in Table 2.8.

2.8.9. Inlet and Outlet Grates

Culverts under driveways and roadways less that 25 m in length shall not normally require inlet and outlet grates. Culverts 25 m and longer shall be equipped with inlet and outlet grates for pipe sizes larger than 300 mm up to and including 1050 mm diameter, unless otherwise directed by the Engineer.

Culverts with pipe size greater than 1050 mm diameter, regardless of length, shall not require inlet and outlet grates, unless otherwise required by the Engineer.

Inlet grates shall be constructed of vertically oriented bars. Outlet grates shall be constructed of horizontally oriented bars. Design and sizing of inlet and outlet grates must account for the restriction in flow created by the grate and blockage. Under no circumstances shall a culvert be equipped with an outlet grate and not an inlet grate. Generally, the cross sectional area of the grate shall be 5 to 10 times the cross sectional area of the pipe. Placement of the grate shall be at least one pipe diameter from the end of the pipe.

2.8.10. Culvert Materials

Culverts under driveways shall be as per the *City of Saint John General Specifications, latest revision*.

Culverts under roadways shall be reinforced concrete pipe (RCP), unless approved otherwise by the Engineer.

2.9 Downstream Effects

2.9.1. Other Considerations

Explicit consideration shall be given to public safety, New Brunswick Department of Environment (NBDOE) regulations, New Brunswick Department of Transportation (NBDOT) regulations, nuisance, and maintenance implications of ditches, open channels, and drainage courses. Attempts shall be made to limit the number of partial enclosures of a ditch, open channel, or drainage course by driveways, roadways, and other crossings.

2.9.2. Stormwater Control Facilities

Investigation of requirements to mitigate the downstream effects of a proposed development shall be carried out to determine the requirements for and feasibility of utilization of a storage facility for stormwater runoff control. If a determination is made that a storage facility is required, its design shall be carried out using appropriate methods and sound engineering principles. The design shall take into consideration various factors including, but not limited to, watercourse protection, erosion and sediment control, impact on adjacent property, maintenance requirements, public safety, access, liability, and nuisance.

Such storage facilities shall be designed to control the peak runoff conditions for various storm events up to the 100 year return period storm.

2.9.3. Storm Drainage Easement for Municipal Services

No storm drainage is to be carried onto, through, or over private property, other than by a watercourse, excavated ditch, or minor storm drainage system. To ensure access to storm drainage systems, the Developer is to secure for conveyance to the City, easements for municipal services of adequate width in the following cases:

- Excavated ditches or storm sewers within the boundary of the subdivision;
- Where a need is identified by the City to accommodate future upstream drainage, an easement for municipal service shall run from the roadway to the upstream limits of the subdivision;
- An easement for municipal services may be required for excavated ditches or minor storm drainage systems that are adjacent to and immediately downstream of the subdivision that are required to ensure proper functioning of the subdivision storm drainage system. An easement for municipal services will not normally be required for a watercourse;
- Where subdivision stormwater runoff flows from the subdivision onto adjacent properties other than in a watercourse, an easement for municipal services in favour of the City of Saint John must be provided by the owners affected;
- Watercourses shall not normally be carried in roadside ditches or minor storm drainage systems.

2.9.4. Discharge to Adjacent Properties

All storm drainage is to be self-contained within the subdivision limits, except for natural drainage associated with runoff from undeveloped areas. However, runoff from within the subdivision may be directed to a natural stream, watercourse, or a municipal storm drainage system.

In all cases, concentration and conveyance of stormwater to adjacent properties outside the subdivision limits is prohibited unless the developer obtains the necessary agreements from the adjacent property owners.

The grading along the limits of the subdivision shall be carefully controlled to avoid disturbance of adjacent properties or an increase in the discharge of stormwater to those properties.

The lot grading design shall provide for drainage from adjacent properties where no other alternative exists.

The lot grading design shall provide for temporary drainage of all blocks of land within the subdivision that are intended for future development.

During the design of storm drainage systems, provision must be made for accommodating natural drainage from adjacent properties by means of an interceptor swale or other system components.

2.10 Analysis of Existing Storm Drainage Systems

In the absence of existing storm drainage master planning, it may be necessary to analyze the capacity of existing storm drainage systems. This may be required in the event a proposed development increases stormwater runoff to an existing system, and it is unknown if the existing system can convey the additional flows without problems. It may also be necessary to analyze an existing system due to complaints of flooding or problems in the system. Where Consultants are required to analyze an existing storm drainage system within the City of Saint John, the following procedure shall be followed:

2.10.1. Hydrologic Analysis

Where existing systems are being analyzed, it is important to determine the peak stormwater runoff to a given point in a system caused by severe rainfall and snowmelt events. Where storage facilities are included in the analysis, it may be necessary to determine the hydrograph of the stormwater runoff to a particular point; that is, the simple instantaneous peak flow will not be adequate to analyze storage facilities. In determining the stormwater runoff or hydrographs, the methods as described in Section 2.4 shall be used.

In preparing the hydrologic and hydraulic model, it is necessary to determine the drainage area to each individual storm manhole and each individual storm inlet. This information shall be compiled on a master drawing of the area being studied with appropriate labels for the areas, manholes, and catchbasins such that calculations can be easily compared to the plan. For minor storm drainage systems, ie. storm sewers and catchbasins, the 1 in 5 year return period storm runoff shall be calculated for the points of interest. For open channels, watercourses, and major drains on streets, the 1 in 100 year return period storm runoff shall be calculated for the points of interest.

2.10.2. Hydraulic Analysis

For each component of the existing storm drainage system such as: a storm sewer main, open channel, watercourse, or culvert, the hydraulic capacity of that portion of the system must be determined and compared to the flow derived from the hydrologic calculations. The following procedures are accepted for determining the hydraulic capacity of storm drainage structures:

2.10.2.1. Open Ditches, Channels, and Watercourses

The Manning's equation may be used to determine the capacity of open channels, ditches, and watercourses where channel slopes are greater than 1%. Where channel slopes are less than 1%, it may be necessary to account for backwater effects using the energy equation and the direct-step or standard-step methodologies. This may be accomplished with a water surface profile model as per Section 2.4. Also to be considered in these calculations is the water surface elevation at the outlet of the ditch, watercourse, or channel.

2.10.2.2. Culverts

To calculate the hydraulic capacity of a culvert, the inlet capacity of the culvert and the outlet capacity shall be checked taking into consideration maximum tailwater elevation at the outlet of the culvert. Also to be checked is the barrel capacity of the culvert using the Manning's equation.

2.10.2.3. Minor Storm Sewer System

Minor storm sewer systems consist of storm sewer mains, manholes, catchbasins, and various inlets and outlets. The capacity of a storm sewer system shall be checked as follows:

- Preliminary sizing of pipe diameter assuming full flow conditions for each pipe in the minor storm drainage system using the Manning's equation for the 1 in 5 year return period storm. Manning's roughness coefficients (*n*) have been tabulated in Table 2.11. The ratio of the 1 in 5 year design flow (Q_5) to full flow pipe capacity (Q_{cap}) shall not exceed 80%.

$$\frac{Q_5}{Q_{cap}} \leq 0.80 \qquad [2.3]$$

where:

Q_5	1 in 5 year design flow (L/s)
Q_{cap}	full flow pipe capacity (L/s)

- A determination of the hydraulic grade line (HGL) for the 1 in 5 year return period storm shall be conducted assuming the actual captured flow (Q_c) is 100% of the 1 in 5 year design flow (Q_5). Analysis shall account for pipe friction losses, junction and bend losses, outlet tailwater elevation, and capacity constraints of the downstream system. HGL profiles may be determined by the standard-step method, the direct-step method, or acceptable energy equation principles. The HGL profile shall be plotted on the plan and profile drawing to ensure that the water surface profile is contained within the pipe. An elevated HGL may require a pipe diameter larger than that which is determined by the Manning's equation in order to avoid surcharging of the minor storm sewer system.
- A determination of the hydraulic grade line (HGL) for the 1 in 100 year return period shall be conducted assuming the actual captured flow (Q_c) is some percentage of the 1 in 100 year design flow (Q_{100}). The actual captured flow shall be the lesser of the maximum catchbasin inlet capacity, the maximum catchbasin lateral capacity, or the 1 in 100 year design flow (Q_{100}). Analysis shall account for pipe friction losses, junction and bend losses, outlet tailwater elevation, and capacity constraints of the downstream system. HGL profiles may be determined by the standard-step method, the direct-step method, or acceptable energy equation principles. The HGL profile shall be plotted on a profile drawing to ensure that the water surface profile is at an acceptable level. The HGL profile shall not cause back-up into service laterals or basements.
- Provision of inlet control devices (ICDs), as presented in Appendix C, is an acceptable means of limiting the actual captured flow (Q_c) by the minor system in storm events that exceed the design capacity of the minor storm sewer system. Design capacity (Q_{des}) of the major storm drainage system must account for any additional flow restricted from entering the minor storm drainage system.

2.10.2.4. Stormwater Detention Structures

Components of a storm drainage system may include natural ponds, lakes, or man-made storm drainage detention facilities to reduce the peak flow downstream. The following procedures shall be used to check the performance of a storm drainage detention facility:

- A 1 in 100 year return period, 24-hour duration storm shall be applied to the watershed using one of the applicable models in Section 2.4. A hydrograph shall be generated to compare pre-development and post-development flow rates.
- The storage indication method shall be used to calculate the outflow from the facility taking into consideration the outlet condition (that is, the hydraulic outlet structure of the pond). The maximum flood elevation of the facility shall be calculated as part of this work. Where the watershed is mostly urban or developed land, it is likely that a summer storm will be adequate to check the facility. However, if a large portion of the watershed is forested or natural, it will be necessary to check the facility using a winter storm with snowmelt included in the runoff.

Table 2.11 Manning's Roughness Coefficient (*n*) for Open Channel Flow and Piped Flow

Material	Description	Manning's Roughness Coefficient (*n*)
Closed Conduits	Asbestos-Cement Pipe	0.011 to 0.015
	Brick	0.013 to 0.017
	Cast Iron Pipe (Cement Lined)	0.011 to 0.015
Concrete	Concrete (monolithic)	0.012 to 0.014
	Reinforced Concrete Pipe (RCP)	0.011 to 0.015
Corrugated Steel Pipe	Corrugated Metal Pipe (plain)	0.022 to 0.026
	Corrugated Metal Pipe (paved invert)	0.018 to 0.022
	Corrugated Metal Pipe (spun asphalt lined)	0.011 to 0.015
Plastic Pipe PVC/HDPE	Ribbed	0.010 to 0.012
	Plain	0.009 to 0.011
Vitrified Clay	Vitrified Clay Pipe	0.011 to 0.015
	Vitrified Clay Liner Plate	0.013 to 0.017
Lined Channels	Asphalt	0.013 to 0.017
	Brick	0.012 to 0.018
	Concrete	0.011 to 0.020
	Rubble or Riprap	0.020 to 0.035
	Vegetal	0.030 to 0.400
Excavated Channels	Earth, straight and uniform	0.020 to 0.030
	Earth, curved and uniform	0.025 to 0.040
	Rock	0.030 to 0.045
	Unmaintained	0.050 to 0.140
Natural Channels	Regular section	0.03 to 0.07
	Irregular section with pools	0.04 to 0.10

2.11 Off-Street Drainage Systems

2.11.1. General

A complete and properly functioning Storm Drainage System includes a variety of components which may be grouped into two categories:

- "Community Systems" being those elements which serve two or more properties. For example: roadside ditches, culverts, roadways, curbs and gutters, street and backyard catchbasins, pipes or conduits, detention ponds, watercourses, floodplains, drainage swales, and ground elevations along common lot lines or in easements.
- "Individual Lot Systems" being those elements which serve a single lot and are contained within its limits. For example: swales contained within lot limits, gently graded lot areas, slopes, roof downspouts, individual seepage pits, French Drains, building laterals, parking lot catchbasins and conduits.

The City is the administrator of subdivision and building construction for the City of Saint John. Within this context, it is an objective of the City of Saint John to facilitate and regulate the establishment of a complete and properly functioning Storm Drainage System to serve new building construction.

An important group of elements in a Storm Drainage System are the Community Systems located outside of the street limits. Poor off-street grading and drainage can lead to unsafe conditions, extensive and costly maintenance, property damage, and loss of use of lot areas.

The primary purpose of this section of the Storm Drainage Design Criteria Manual is to facilitate and regulate design and construction with respect to the Community Systems located outside of the street limits.

2.11.2. Roles and Responsibilities

Several parties are typically involved in the design, construction, and maintenance of the Community Systems providing off-street drainage. Their roles and responsibilities within the context of this section of the Storm Drainage Design Criteria Manual are described as follows:

- Consultant
  The Consultant is responsible for the preparation of the design of the Community Systems, such that when construction of the design takes place, the objectives of the Storm Drainage Design Criteria Manual are met. In carrying out this responsibility, the Consultant is to provide for adequate initial construction such that undue ongoing maintenance obligations are not placed on the Homeowner or the City.

- Contractor
  The Contractor is responsible for the construction of the Community Systems in accordance with the design and provisions required by the City and in a good and workmanlike manner. It is required that the Contractor not deviate from the design without prior consultation with the Consultant. If unusual or unanticipated site conditions are encountered during construction, the Contractor shall advise the Consultant immediately.

- Developer
  The Developer is the owner of the land proposed for subdivision or development, and includes anyone acting as his/her agent. With respect to lot grading and drainage, the Developer is responsible for construction of the Community Systems identified by the Engineer as being the Developer's responsibility. This will include construction works within easements, be they public or private, and in certain instances will involve pre-grading

of entire lot areas to prevent ponding of water or other drainage problems. Construction of grades along common lot lines and grading of entire lots where community grading concerns do not exist will generally not be required.

- City
  The City of Saint John is the administrator of the process associated with design, construction, and certification of the Community Systems. As part of this process, the City may review, approve, and provide comment to the other parties. As the administrator of the process, the City does not assume any responsibility for the actions of the other parties. In some instances, the City may be responsible for the maintenance of the off-street Community Systems located within public easements.

- Homeowner
  It is expected that the Homeowner will be responsible for the usual maintenance of the Individual Lot Systems, and in some instances, of the Community Systems, eg. cleaning of storm drainage inlets, maintaining drainage swales free of vegetation and debris, and maintaining suitable slope protection. It is expected that Homeowners will not block drainage routes, for example, placing excess snow at end of driveway thereby blocking sideyard drainage swales. If the Homeowner alters any of the Community Systems, he/she shall be responsible for the implications of the alteration.

2.11.3. Objectives

The Community Systems designed within the context of the Storm Drainage Design Criteria Manual shall achieve the following objectives:

a) to prevent loss of life and protect structures and property from significant damage and expense, including that which is expected to be experienced during a 1 in 100 year storm event.
b) to provide for convenient and reasonable use of lot areas despite the existence of overland flow during and following rain and snow events and the existence of subsurface or groundwater flow, eg. continuously saturated backyard, significant continuous icing.
c) to provide for safe use of lot and street areas, eg. excessive depth of flow or water storage, significant continuous icing.
d) to avoid drainage problems or other conditions that result in unreasonable maintenance obligations on the Homeowner or City, eg. significant or regular de-icing operations.
e) to provide protection from erosion from surface flow, subsurface flow, or groundwater, eg. slope stabilization.
f) to direct water away from buildings in order to prevent basement flooding and damage to the foundation drain.
g) to prevent standing water and soil saturation detrimental to buildings, driveways, walkways, landscaped areas and other use of the lot.

In addition to the foregoing, the Consultant is to provide information to the City to demonstrate that the following overall Storm Drainage System objectives are achieved:

h) to adequately convey stormwater flow from upstream sources.
i) to prevent and/or mitigate the adverse effects of stormwater flow on downstream or adjacent properties, such as erosion, or flooding due to inadequate downstream capacity or grading.
j) to preserve watercourses.
k) to minimize the long term effect of development on receiving watercourses and groundwater.
l) to maintain pre-development drainage patterns unless some motivating factor to change the pattern exists, eg. conflict with other objectives (capacity).

In the preparation of a design that meets the above objectives, the Consultant is encouraged to strive for an attractive living environment and give consideration to factors such as the following:

- Aesthetic conditions relating to lot grading, eg. creating space on the lot that is convenient as a play area, usually in the backyard.
- The preservation of desirable site features where practical, ie. minimizing disturbance, retaining trees.
- Providing for variance in front yard setbacks along a street and for establishing a roof line profile which is aesthetically pleasing.
- Locating slopes and boundary lines such that tops and bottoms of slopes are at property boundaries.
- Avoiding excessively deep swales.
- Where swales and French Drains are contemplated at the base of a significant slope, it is recommended that the swale be located at the toe of the slope.
- Locating driveway to allow convenient and safe ingress and egress.
- Creating consistent grading within adjacent lots.

2.11.4. Design Criteria – Off-Street Systems and Subdivision Grading

The Design Criteria for lot grading and drainage are to cover the more common aspects of design encountered in lot grading and drainage development. Local conditions may influence the design criteria and design requirements, for example, circumstances where soils are not free draining may require a flatter maximum permissible slope. Additional requirements affecting design are contained in other relevant documents, such as the National Building Code of Canada.

The Criteria provided herein are for information and will serve as the benchmark for review of Subdivision Grading Plans in typical circumstances.

2.11.4.1. Community Systems

In designing Community Systems, the focus is on those drainage elements which affect more than one property, eg. common backyard swales/catchbasins, grading along common property boundaries. It is critical that the Consultant ensure that sufficient Community Systems are in place and/or contemplated and depicted such that the Individual Lot Systems can be designed and constructed in a fashion that allows for a properly functioning overall Storm Drainage System for the Homeowner while striving for an attractive living environment. It is intended that Community Systems will not have to be altered as a consequence of design of detailed Individual Lot Systems. Therefore, it is strongly recommended that the Consultant test the ability of the Community Systems to achieve the above stated objective by carrying out preliminary design of the Individual Lot Systems serving the lots.

Community Systems are to be designed in accordance with the following criteria:

Ground Surface

- The area between the street right-of-way and the curb shall slope towards the curb at a minimum slope of 2% but not greater than 4%.
- The maximum slope shall be 3:1 (H:V) unless constructed on in-situ rock. A steeper slope may also be permitted by the Engineer if a geotechnical report is submitted that certifies the use of a steeper slope. The top and bottom of banks shall be rounded for convenient maintenance. Notwithstanding the foregoing, the Consultant is responsible to design a suitably graded slope with appropriate surface treatment to provide for long term stability.

- Where required, retaining walls shall be designed with due consideration given to soundness of material, stability, safety, maintenance and other relevant factors. Retaining walls with a height greater than 1 m shall be designed by and the construction certified by a Professional Engineer.
- Where a cut intercepts the groundwater table creating potential drainage and icing problems, special measures will be required to address potential drainage problems. Such systems may include local drain tile systems or French drains.
- Where areas are disturbed, stabilization is to be provided to prevent erosion.

<u>Off-Street Swales</u>

- Except for individual single family and semi-detached dwelling lots, provision shall be made to collect on-site, and convey by pipe to a storm sewer, all runoff from off-street areas other than grassed or undisturbed areas.
- Swales shall be blended into the landscape to the greatest degree possible in order to provide a natural appearance.
- The minimum grade along any swale shall be 2%. Less than 2% grade may be used where underdrains are incorporated. In cases where an underground drain is included in the swale design, the minimum grade may be reduced to 1%. Consultants are encouraged to use grades, where possible, that are steeper than the minimum.
- The flow from all swales shall be intercepted by catchbasins at a maximum spacing such that the maximum depth of flow in the 5 year storm event is 100 mm or as otherwise directed by the Engineer.
- Where the swale intercepts subsurface water, the swale shall incorporate underdrains, regardless of slope.
- The side slope for any swale shall be no greater than 33% (3 horizontal: 1 vertical).
- The maximum depth of flow in any swale shall be 250 mm in the 1 in 100 year storm.
- All swales shall be designed to accommodate the 1 in 100 year stormwater flow.
- An overflow route shall be provided to direct overflow to major storm drainage systems. The 1 in 100 year water level along such route shall be lower than the lowest opening to the adjacent dwellings.
- Sharp corners shall be avoided in swale design.
- Steeply sloping swales shall have appropriate surface treatment to prevent erosion.

<u>Catchbasins</u>

- Where a swale intersects a street, a catchbasin, located as close as practical to the curb or to the sidewalk, shall be installed to intercept flow from the swale.
- The flow from all rear yard swales serving a significant number of lots shall be intercepted by a catchbasin(s) installed at the rear of the property.
- The grade of lots in the immediate vicinity of a rear yard catchbasin shall be graded in a manner which will direct all water to the catchbasin.
- Catchbasins shall be located entirely on one property and shall not be located on any property line.

<u>Underdrains</u>

- Underdrains are to be used to remove surface and subsurface water, to drain wet areas and other areas of poor drainage, or where minimum slopes with respect to lot surface or swales cannot be achieved.

- Underdrains are not permitted to discharge onto street surfaces, walkways, private properties, or any other location where there would be an impact inconsistent with the objectives of this Manual.
- Underdrains shall be located a minimum of 3 m away from any part of the building foundation.
- Where necessary to avoid icing problems on the street caused by water flowing over the top of the curb, the Consultant shall provide an acceptable method to intercept this flow, eg. French drain installed behind the curb.
- Small diameter pipe (less than 250 mm diameter) installed for “off-street” drainage such as French drains, and rear yard drains may be installed without manholes provided the following conditions are met:
  - the pipe discharge must be into a catchbasin or manhole within the street right-of-way,
  - where two or more lines join, a manhole shall be provided,
  - where such lines are greater in length than 25 m, a wye type clean-out or manhole shall be installed in locations as approved by the Engineer,
  - a wye type clean-out, manhole or catchbasin shall be provided at the end of each line,
  - long radius bends may be used provided that a wye type clean-out is installed on the upstream side of each fitting.

Easements

- Easements shall be provided for all swales which, in the opinion of the Engineer, require such legal conveyances.
- Easements for municipal services shall be provided for all catchbasins and associated stormwater pipes constructed in conformance with the City’s standards.
- A minimum easement width of 6 m is required for public easements.
- A minimum easement width of 4.5 m is required for private easements.

2.11.5. Multi-Unit Residential, Institutional, Industrial and Commercial Buildings

Although ownership of the storm system and responsibility for maintenance shall remain private, design of the Storm Drainage System for multi-unit residential, institutional, industrial, and commercial buildings shall conform to the *Storm Drainage Design Criteria Manual*.

Multi-unit residential, institutional, industrial, and commercial developments shall employ flow control devices upstream of the central storm sewer connection, which will limit the peak flow to the pre-development flow for both the minor and major storm. As an option and at the discretion of the Engineer, the Consultant may undertake an analysis of the downstream receiving system in accordance with Section 2.2.5, and if it can be demonstrated that excess capacity exists beyond that required for full development of the tributary watershed, the Engineer may permit a greater release rate of peak flow from the development.

2.12 Erosion and Sedimentation Control

Stormwater management systems shall be an integral part of overall site design and development. The Consultant shall submit an erosion and sedimentation control plan in conformity with all applicable municipal and provincial regulations and guidelines. The plan shall include both short-term measures applicable during construction and long-term measures after completion of development.

Site design shall make optimum use of existing topography and vegetation and minimize cut and fill operations. During construction, site design shall prevent/minimize surface water flows across or from the construction site. Development of the site shall be based on exposing a minimum area of the site for the minimum time.

The control plan shall include the following:

- interception and diversion ditches to direct clear water around the construction site
- stable diversion berms
- sediment traps
- covering or seeding of topsoil or other soil stockpiles
- isolated stripping of land being developed
- vegetation screens or buffers
- filter bags in catchbasins
- settling ponds

Long-term environmental protection measures shall include designs to minimize erosion and sediment flow, protect outfall areas, minimize disruption of watercourses, utilize wetlands for natural filtration, and provide for groundwater recharge when possible.

Reference documents applicable for use by the Consultant in preparing Erosion and Sediment Control Plans include:

- *Watercourse Alterations Technical Guidelines*, Province of New Brunswick Department of Environment
- *Environmental Field Guide*, New Brunswick Department of Transportation
- *Environmental Protection Plan*, New Brunswick Department of Transportation

3 SUBMISSION REQUIREMENTS

3.1 Scope

The submission requirements presented in this section outline the requirements of the City for the purposes of the review of engineering design only.

A Developer proposing to develop or subdivide an area of land must submit to the City for approval all plans, technical briefs, and supplementary calculations required and as outlined herein.

Additional copies of any plans, technical briefs, and supplementary calculations as deemed necessary by the City for any government department, public utility, or Crown Corporation must be submitted for review.

Approval of the storm drainage design by the City does not in any way relieve the Consultant of the responsibility for proper design with respect to the plans, technical briefs, and supplementary calculations for compliance with this document.

3.2 Municipal Infrastructure

If the subdivision requires the installation or upgrading of any storm drainage infrastructure, the following information must be provided.

- Two (2) paper copies of the Storm Drainage Plan prepared in accordance with Section 3.4.
- Two (2) paper copies of the Subdivision Grading Plan prepared in accordance with Section 3.5.
- Two (2) paper copies of the Erosion and Sedimentation Control Plan prepared in accordance with Section 3.6.
- Two (2) paper copies of the Engineering Design Brief prepared in accordance with Section 3.7.

3.3 Drawing Requirements

3.3.1 General

All Storm Drainage Plans, Subdivision Grading Plans, and Erosion and Sedimentation Control Plans must be prepared under the direct supervision of, and be signed and sealed by a member, or a Licenced to Practice member, of the Association of Professional Engineers and Geoscientists of New Brunswick (APEGNB).

3.3.2 Units

Plans must be submitted in SI units on standard size drawing sheets.

3.3.3 Scale

Wherever possible, plans are to be drafted in one of the following standard metric ratios:

- 1 : 250
- 1 : 500
- 1 : 1,000
- 1 : 2,000

A graphic bar scale is to be provided on all plans.

3.4 Storm Drainage Plan

Storm Drainage Plans, in addition to the requirements of Section 3.3, must include the following in either graphic and/or tabular form:

- the location of the subdivision within the total topographic drainage area;
- site layout including proposed streets, lots and approximate location of proposed structures;
- pre-development contours based upon available mapping (2 m interval preferred), including provision for upstream areas;
- all existing watercourses including ponds, swamps and wetlands indicating direction of flow;
- location and layout of the minor storm drainage system including manholes, catchbasins, and storm sewer indicating pipe material, diameter, slope, and direction of flow;
- boundaries of catchment and subcatchment areas tributary to each set of catchbasins, and/or pipes indicating the area, runoff coefficients;
- size and location of any proposed post-development storage facilities;
- predominant direction of surface flow including the flow route of the major storm drainage system;
- location of outfalls, or connection to existing systems, for both the minor storm drainage system, and the major storm drainage system;
- any additional information deemed necessary by the City of Saint John Municipal Operations and Engineering Department.
- 1 in 100 year flood limits of watercourse along with 1:100 year flood elevations.

3.4.1 Supplementary Calculations

In addition to the above requirements, the Developer must submit to the City computational sheets, and related model output used to determine:

- Manning's capacity analysis
- Hydraulic grade line analysis
- Major drain depth and spread of flow

3.5 Subdivision Grading Plan

Subdivision Grading Plans, in addition to the requirements of Section 3.3, must include the following:

- site layout including proposed streets, lots and approximate location of proposed structures;
- pre-development contours at an interval not exceeding 1 m;
- proposed landscaping features on each lot including driveways, parking lots, and grassed areas;
- proposed finished grade elevations at the following locations:
  - centreline of streets
  - corners of all lots, easements, and walkways
  - proposed foundation wall elevation
  - proposed basement floor elevation
  - proposed drainage swales or ditches
- pattern and direction of post-development surface drainage including lots, swales, and major storm drainage system;
- location and layout of the minor storm drainage system including manholes, catchbasins, and storm sewer.

3.6 Erosion and Sedimentation Control Plans

Erosion and Sedimentation Control Plans, in addition to the requirements of Section 3.3, shall include the following:

- a brief description of the project, including: the date the project is to begin and expected date that final stabilization will be completed, and the phasing of land-disturbing activities and site stabilization to minimize the extent of exposed areas.
- topographic features, including: the location of the project relative to roadways, property boundaries and other identifiable landmarks, contours at an interval that will adequately describe the area, critical environmental areas located within or in close proximity of project areas, and nature and extent of existing vegetation.
- information on the soils, including description of various soils.
- the proposed alteration of the area, including: boundary limits and acreage of the project, limits of clearing and grading, areas of cuts and fills and proposed side slopes, location of roads, and location and protection of stockpiles of excess fill or topsoil.
- the temporary erosion and sedimentation control measures to be used during active construction, including; types of measures and facilities and expected length of service, location of measures and facilities, and dimensional details.
- the permanent erosion and sedimentation control measures for long-term protection, including: types of measures and facilities, location of measures and facilities, dimensional details of facilities, and landscaping and vegetative details such as seeding, sodding or mulching.
- the maintenance program for the control facilities, including: inspection program, frequency and schedule, repair or reconstruction of damaged measures and facilities, method and frequency of removal and disposal of sediment from the control facilities, and method for disposing of temporary structural measures after they have served their purposes.

3.7 Engineering Design Brief

In an effort to facilitate the review and approval of proposed subdivision plans, the Consultant is required to submit to the City an Engineering Design Brief which outlines and summarizes design assumptions and approaches contained within the subdivision submission.

The Engineering Design Brief shall provide commentary on the storm drainage system design, the subdivision grading design, and the erosion and sedimentation control plan.

The Engineering Design Brief shall clearly identify where design assumptions and approaches are consistent with recommendations set forth in the *City of Saint John Storm Drainage Criteria Manual* and must clearly identify where design assumptions and approaches have deviated from the recommendations set forth in the *City of Saint John Storm Drainage Criteria Manual*, along with supporting documentation and test results to justify the deviations from the established recommendations.

4 References

American Concrete Pipe Association 1980. Concrete Pipe Design Manual. American Concrete Pipe Association, Vienna, VA, 486 pp.

American Concrete Pipe Association 1980. Concrete Pipe Handbook. American Concrete Pipe Association, Vienna, VA.

American Iron and Steel Institute 1984. Handbook of Steel Drainage & Highway Construction Products, Canadian Edition. American Iron and Steel Institute, Washington, DC, 413 pp.

American Society of Civil Engineers 1970. WPCF Manual of Practice No. 9, ASCE Manuals and Reports on Engineering Practice No. 37, Design and Construction of Sanitary and Storm Sewers. Water Pollution Control Federation, Washington, D.C., 332 pp.

Association of Professional Engineers and Geoscientists of New Brunswick. Recommended Standards for Water and Sewer Projects.

Brown, S.A., Stein, S.M., & Warner, J.C. 1996. Urban Drainage Design Manual, Hydraulic Engineering Circular 22. U.S. Department of Transportation, Federal Highway Administration, FHWA-SA-96-078, 478 pp.

Chow V.T., Maidment D.R., and Mays L.W. 1988. Applied Hydrology. McGraw-Hill Book Company, New York, NY, 572 pp.

Chow, V.T. 1959. Open-Channel Hydraulics. McGraw-Hill Book Company, New York, 680 pp.

City of Moncton. City of Moncton Design Criteria Manual for Municipal Services.

Cronshey R., et al. 1986 Urban Hydrology for Small Watersheds. United States Department of Agriculture, United States Soil Conservation Service, Technical Release 55, 2nd Edition.

Environment Canada 1982. Canadian Climate Normals – Volume 3 – Precipitation, 1951-1980. Environment Canada, Atmospheric Environment Service, Canadian Climate Program, Ottawa, ON, 601 pp.

Environment Canada 1993. Canadian Climate Normals - 1961-1990 – Atlantic Provinces. Environment Canada, Atmospheric Environment Service, Canadian Climate Program, 105 pp.

Haestad Methods, Inc. 1997. 1997 Practical Guide to Hydraulics and Hydrology. Haestad Press, Waterbury, CT, 216 pp.

Halifax County Storm Drainage Task Force 1982. Recommendations and Stormwater Policy.

Halifax County Storm Drainage Task Force 1982. Design Criteria Manual.

Halifax Regional Municipality. Halifax Regional Municipality Municipal Service Systems General Specification (Red Book).

Henderson F.M. 1966. Open Channel Flow. MacMillan Publishing Co., Inc., New York, NY, 552 pp.

Hogg W.D., and Carr D.A. 1985. Rainfall Frequency Atlas for Canada. Environment Canada, Atmospheric Environment Service, Ottawa, ON.

Marshal Macklin Monaghan Limited 1994. Stormwater Management Practices Planning and Design Manual. Ontario Ministry of Environment and Energy, Environmental Services & Standards Development Branch, Toronto, ON, 260 pp.

New Brunswick Department of Transportation, August 1998. Environmental Field Guide.

New Brunswick Department of Transportation, May 1998. Environmental Protection Plan (third edition)

Nova Scotia Department of the Environment. Erosion and Sedimentation Control Handbook for Construction Sites.

Province of New Brunswick Department of the Environment and Local Government, Regional Services Branch. Watercourse Alterations Technical Guidelines.

Smith C.D. 1985. Hydraulic Structures. University of Saskatchewan Printing Services, Saskatoon, SK, 357 pp.

Townshend D.R., Wisner P.E., and Moss D.J. 1980. Inlet Control Devices for Stormsewer Catchbasins: A Laboratory Study. University of Ottawa, Faculty of Science and Engineering, Department of Civil Engineering, Ottawa, ON.

Union of Concerned Scientists, IPCC Highlights Series 2007. Findings of the IPCC Fourth Assessment Report, Climate Change Science.

Uni-Bell PVC Pipe Association 1991. Handbook of PVC Pipe Design and Construction, Uni-Bell PVC Pipe Association, Dallas, TX, 474 pp.

United States Environmental Protection Agency, 1983. Results of the Nationwide Urban Runoff Program. Water Planning Division, US Environmental Protection Agency

Watt W.E., et al. 1989. Hydrology of Floods in Canada – A Guide to Planning and Design, National Research Council of Canada, Associate Committee on Hydrology, Ottawa, ON, 245 pp.

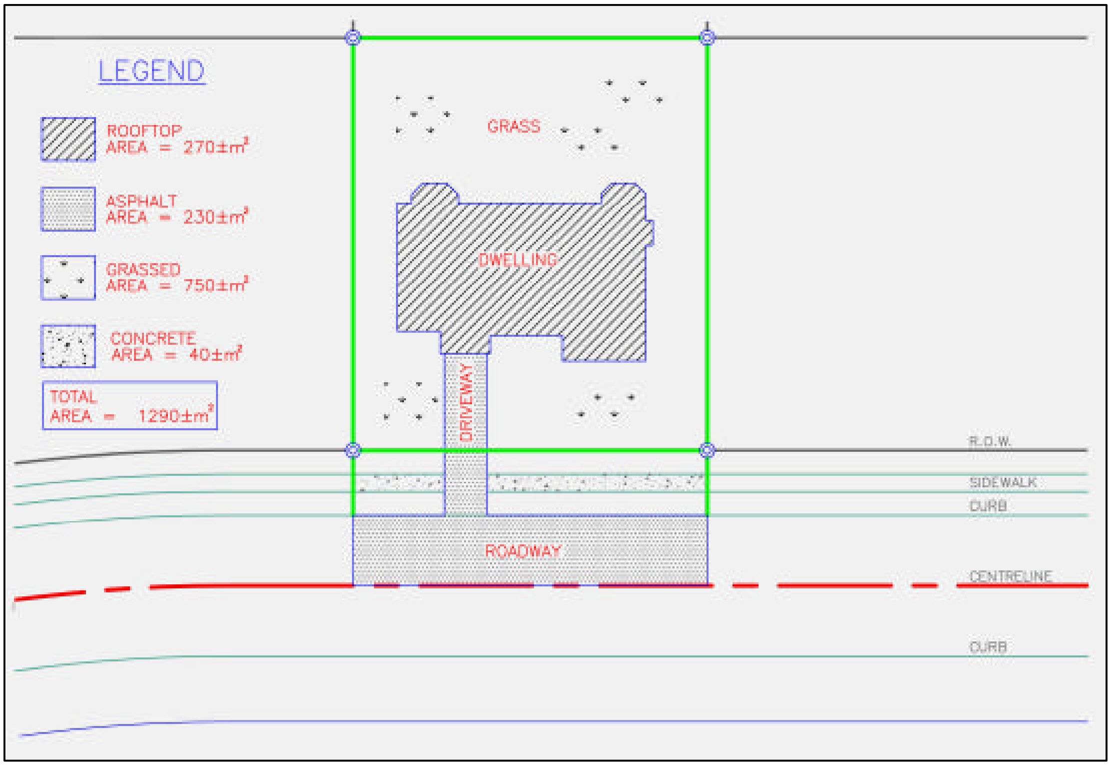
Whipple W., et al 1983. Stormwater Management in Urbanising Areas. Prentice-Hall, Inc., New Jersey, 234 pp.

Wisner P.E. 1990. Protection of Basements Against Flooding – Trends and Impact of Drainage Regulations, Canada Mortgage and Housing Corporation, External Research Program.

Water Pollution Control Federation. Manual of Practice No. 9.

APPENDIX A – Calculation of Composite Rational Method Runoff Coefficient (C*) and Composite USSCS Method Curve Number (CN*)

Figure A.1 - Typical Single Family Residential Lot



Example A.1(a)

Calculation of Composite Rational Runoff Coefficient (*C)**

Given: Figure A.1 presents surface materials and surface areas for a typical single-family residential lot.

Determine: Determine the composite Rational runoff coefficient (*C**).

Step 1: The composite Rational runoff coefficient (*C**) may be determined by the following equation:

$$C^* = \frac{\sum C \cdot A}{\sum A} \quad [A.1]$$

where:

*C** = composite Rational runoff coefficient
C = Rational runoff coefficient (from Table 2.2)
A = area (m^2)

Table A.1 was created using the surface material and surface areas presented in Figure A.1, and the Rational runoff coefficients presented in Table 2.2. The composite Rational runoff coefficient was determined from Equation [A.1].

Table A.1 Composite Rational Method Runoff Coefficient (*C) Calculation**			
Surface Material	**Runoff Coefficient C**	**Area A (m^2)**	***C A* (m^2)**
Rooftop	0.95	270	256.5
Asphalt	0.95	230	218.5
Grass	0.17	750	127.5
Concrete	0.95	40	38.0
Total		1290	640.5
Composite Coefficient ($C^*=\sum CA/\sum A$)	**0.50**		

Example A.1(b)

Calculation of Composite USSCS Method Curve Number (*CN)**

Given: Figure A.1 presents surface materials and surface areas for a typical single-family residential lot.

Determine: Determine the composite **USSCS Method** curve number (CN^*).

Step 1: The composite **USSCS Method** curve number (CN^*) may be determined by the following equation:

$$CN^* = \frac{\sum CN \cdot A}{\sum A} \quad [A.2]$$

where:

CN^* = composite **USSCS Method** curve number
CN = **USSCS Method** curve number (from Table 2.5)
A = area (m^2)

Table A.2 was created using the surface material and surface areas presented in Figure A.1, and the **USSCS Method** curve numbers presented in Table 2.5. The composite **USSCS Method** curve number was determined from Equation [A.2].

Table A.2 Composite USSCS Method Curve Number (CN*) Calculation			
Surface Material	**Curve Number CN**	**Area A (m^2)**	***CN A* (m^2)**
Rooftop	98	270	26,460
Asphalt	98	230	22,540
Grass	80	750	60,000
Concrete	98	40	3920
Total		1290	112,920
Composite Curve Number ($CN^*=\sum CNA/\sum A$)	**88**		

APPENDIX B – Computation of Travel Time (Tt) and Time of Concentration (Tc)

Example B.1

Calculation of Travel Time (T_t) Through a Subwatershed

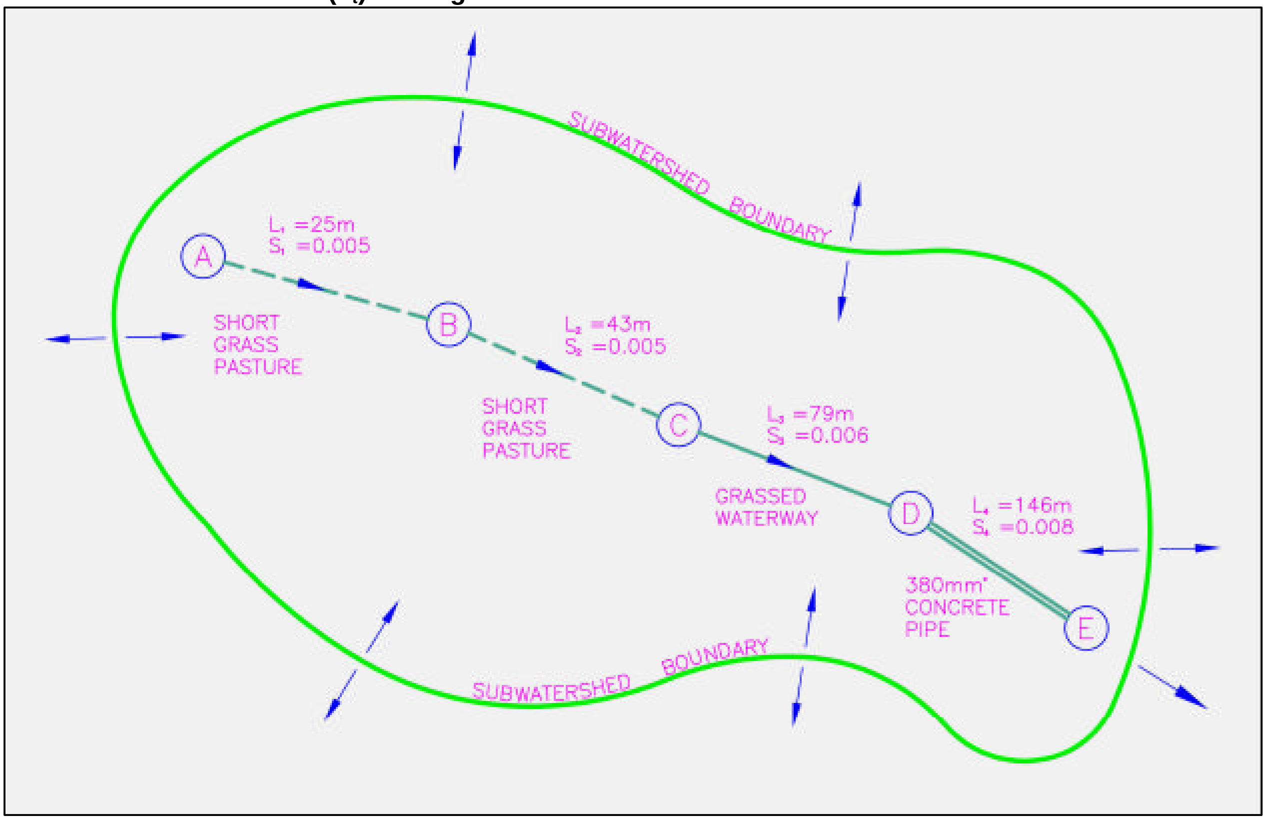


Figure B.1 Overland Flow Through a Typical Watershed

Stormwater runoff is conveyed through a subwatershed by a natural progression of overland flow. Stormwater runoff initiates as overland sheet flow in the most upstream portions of a subwatershed. As overland sheet flow is concentrated into rills and gullies, stormwater runoff is conveyed as shallow concentrated flow. Eventually shallow concentrated flow will further concentrate until it is conveyed to an open channel, or piped system.

A number of methodologies exist for the determination of flow velocity for overland sheet flow, shallow concentrated flow and open channel and piped flow. The United States Soil Conservation Service (USSCS) methodology is presented below.

Overland Sheet Flow

Sheet flow occurs over plane surfaces in the upper reaches of a subwatershed. Sheet flow is normally considered to be limited to a depth of 25 mm, and a flow length of as little as 25 m, and as much as 100 m. The travel time may be determined by a simplification of the Manning's kinematic wave equation expressed as:

$$T_t = \frac{Kc}{I^{0.4}} \bullet \left(\frac{nL}{\sqrt{S}} \right)^{0.6} \qquad [B.1]$$

where:

T_t = travel time (min)
n = effective Manning's roughness coefficient (see Table B.1)
L = flow length (m)
I = rainfall intensity (mm/hr)
S = slope (m/m)
K_c = coefficient = 6.943

The roughness coefficient expressed in Equation [B.1] is the effective Manning's roughness coefficient for sheet flow. The effective roughness coefficient accounts for the effects of raindrop impact, drag, surface irregularities, obstacles, and sediment transport. Table B.1 presents effective Manning's roughness coefficients for various surface conditions suitable for use in Equation [B.1].

Table B.1 Effective Manning's Roughness Coefficient (*n*) for Overland Sheet Flow

Surface Condition	Effective Manning's Roughness Coefficient (*n*)
Smooth asphalt	0.011
Smooth Concrete	0.012
Ordinary Concrete Lining	0.013
Good Wood	0.014
Brick with Cement Mortar	0.014
Vitrified Clay	0.015
Cast Iron	0.015
Corrugated Metal Pipe (CSP)	0.024
Cement Rubble Surface	0.024
Fallow – no residue	0.05
Cultivated Soils – residue ≤ 20%	0.06
Cultivated Soils – residue > 20%	0.17
Range – natural	0.13
Grass – Short Grass Prairie	0.15
Grass – Dense Grasses	0.24
Grass – Bermuda Grass	0.41
Woods[1] – Light Underbrush	0.40
Woods[1] – Dense Underbrush	0.80

<u>Note:</u> [1] *Only ground cover to a height of approximately 30 mm that impedes overland sheet flow shall be considered when selecting the effective Manning's roughness coefficient.*

Shallow Concentrated Flow

Shallow concentrated flow normally occurs as sheet flow is concentrated into rills and gullies of increasing proportion. The velocity may be determined by:

$$V = k \cdot \sqrt{S} \qquad \text{[B.2]}$$

where:

V = velocity (m/s)
k = slope/velocity intercept coefficient (see Table B.2)
S = slope, (%)

Table B.2 Slope/Velocity Intercept Coefficient (*k*) for Shallow Concentrated Flow

Surface Condition	Slope/Velocity Intercept Coefficient (*k*)
Forest with Heavy Ground Litter, Meadow	0.076
Woodland, Trash Fallow, Minimum Tillage Cultivation	0.152
Short Grass Pasture	0.213
Cultivated Straight Row	0.274
Nearly Bare and Untilled, Alluvial Fans	0.305
Grassed Waterway	0.457
Unpaved	0.491
Paved, Small Upland Gullies	0.619

Open Channel Flow Velocity and Piped Flow Velocity

Open channel flow and piped flow normally occurs as shallow concentrated flow from rills and gullies is concentrated. The velocity of open channel flow or piped flow may be determined by the Manning's equation:

$$V = \frac{1}{n} \cdot R^{\frac{2}{3}} \cdot S^{\frac{1}{2}} \qquad \text{[B.3]}$$

where:

V = velocity (m/s)
n = Manning's roughness coefficient for open channel flow (see Table B.3)
R = hydraulic radius (m)
S = slope (m/m)

The hydraulic radius (R) presented in Equation [B.4] is defined as the flow area (*A*) divided by the wetted perimeter (*P*) and may be expressed as:

$$R = \frac{A}{P} \qquad \text{[B.4]}$$

where:

R = hydraulic radius (m)
A = flow area (m^2)
P = wetted perimeter (m)

Table B.3 Manning's Roughness Coefficient (*n*) for Open Channel Flow and Piped Flow		
Material	**Description**	**Manning's Roughness Coefficient (*n*)**
Closed Conduits	Asbestos-Cement Pipe	0.011 to 0.015
	Brick	0.013 to 0.017
	Cast Iron Pipe (Cement Lined)	0.011 to 0.015
Concrete	Concrete (monolithic)	0.012 to 0.014
	Reinforced Concrete Pipe (RCP)	0.011 to 0.015
Corrugated Steel Pipe	Corrugated Metal Pipe (plain)	0.022 to 0.026
	Corrugated Metal Pipe (paved invert)	0.018 to 0.022
	Corrugated Metal Pipe (spun asphalt lined)	0.011 to 0.015
Plastic Pipe PVC/HDPE	Ribbed	
	Plain	0.011 to 0.015
Vitrified Clay	Vitrified Clay Pipe	0.011 to 0.015
	Vitrified Clay Liner Plate	0.013 to 0.017
Lined Channels	Asphalt	0.013 to 0.017
	Brick	0.012 to 0.018
	Concrete	0.011 to 0.020
	Rubble or Riprap	0.020 to 0.035
	Vegetal	0.030 to 0.400
Excavated Channels	Earth, straight and uniform	0.020 to 0.030
	Earth, curved and uniform	0.025 to 0.040
	Rock	0.030 to 0.045
	Unmaintained	0.050 to 0.140
Natural Channels	Regular section	0.03 to 0.07
	Irregular section with pools	0.04 to 0.10

Computation of Travel Time (T_t) and Time of Concentration (T_c)

The travel time (T_t) through a subwatershed, or the time of concentration of a subwatershed (T_c), is the sum of the travel times for each individual sequential segment contained within the flow path.

The travel time (T_t) for an individual flow segment of a subwatershed may be determined by:

$$T_t = \frac{L}{60_{\text{sec}/\text{min}} \cdot V} \quad \text{[B.5]}$$

where:

T_{ti} = travel time for segment *i* (min)
L = flow length for segment *i* (m)
V = average velocity for segment *i* (m/s)

The travel time (T_t), or the time of concentration (T_c) may be determined by the sum of all the individual travel times.

$$T_c = T_t = T_{t1} + T_{t2} + \ldots + T_{tn} \quad \text{[B.6]}$$

where:

T_c = time of concentration (min)
T_t = travel time (min)
T_{tn} = travel time for flow segment n

Example B.2

Calculation of Travel Time (T_t) Through a Subwatershed

Given: The following flow segment characteristics:

Flow Segment	Length (m)	Slope (m/m)	Segment Description
1	25	0.005	short grass pasture
2	43	0.005	short grass pasture
3	79	0.006	grassed waterway
4	146	0.008	375 mm concrete pipe

Determine: The travel time (T_t) for each flow segment, and the travel time (T_t) through the subwatershed for a rainfall intensity (I) of 60 mm/hr.

Step 1: Determine the travel time (T_t) for each flow segment.

Segment 1: The first 25 m of overland flow in the subwatershed occurs as overland sheet flow.

From Table B.1 for short grass pasture, n=0.15.

From Equation B.1
$T_{t1} = (6.943 / 60^{0.4})\ [(0.15 \times 25) / 0.005^{0.5}]^{0.6}$
T_{t1} = 14.6 min

Segment 2: The next 43 m of overland flow in the subwatershed occurs as shallow concentrated flow.

From Table B.2 for short grass pasture, k=0.213.

From Equation B.2
$V_2 = (0.213)\ (0.5)^{0.5}$
V_2 = 0.15 m/s

From Equation B.5
$T_{t2} = (43) / (60 \times 0.15)$
T_{t2} = 4.8 min

Segment 3: The next 79 m of flow in the subwatershed occurs as shallow concentrated flow.

From Table B.2 for grassed waterway, k=0.457.

From Equation B.2
$V_3 = (0.457)\ (0.6)^{0.5}$
V_3 = 0.35 m/s

From Equation B.5
$T_{t3} = (79) / (60 \times 0.35)$
T_{t3} = 3.7 min

Segment 4: The next 146 m of flow in the subwatershed occurs as piped flow.

From Table B.3 for concrete pipe, n=0.013.

From Equation B.4
$R = [\pi \text{ x } (0.375/2)^2] / [2\pi \text{ x } (0.375/2]$
$R = 0.0943$ m

From Equation B.3
$V_4 = [1/(0.013)] \text{ x } (0.093)^{2/3} \text{ x } (0.008)^{1/2}$
$V_4 = 1.4$ m/s

From Equation B.5
$T_{t4} = (146) / (60 \text{ x } 1.4)$
$T_{t4} = 1.7$ min

Step 2: Determine the time of concentration (T_c) for the subwatershed.

From Equation B.6
$T_c = 14.6 + 4.8 + 3.7 + 1.7$
$T_c = 24.8$ min

APPENDIX C – Provision and Design of Inlet Control Devices (ICD)

Minor storm sewer mains are typically designed to accommodate the 1 in 5 year design event. Catchbasin grate capacity and catchbasin lateral capacity are typically designed to accommodate flows in excess of the 1 in 5 year design event.

In a major storm, or any storm event that exceeds the 1 in 5 year design event, catchbasin grates and laterals may capture and convey more stormwater runoff to the storm sewer mains than the mains were originally designed to accommodate. As the excess capacity that is naturally designed into storm sewer mains is consumed, the hydraulic grade line, or the water surface profile under open channel conditions, elevates and approaches a surcharged condition.

Under surcharged, or pressurised conditions, energy losses due to pipe friction and irregularities at manholes are greatly increased over that of open channel conditions. This phenomena further elevates the hydraulic grade line. In extreme cases, elevated hydraulic grade lines may cause backflow into basements resulting in flooding complaints, create disturbance on streets due to surcharged manholes, and may damage the storm sewer system.

In order to minimize the potential for surcharging in the storm sewer system, it is necessary to provide a flow control device capable of conveying the 1 in 5 year design flow, yet restrict additional flow. An inlet control device (ICD) is a flow restriction device designed with this purpose in mind.

Typical ICD configurations are in the form of caps, or plugs designed to fit onto the outlet within the catchbasin, restricting flow from the catchbasin to the storm sewer main. The premise of ICD design is to limit the open area available to flow to a size that will convey only the maximum desired design flow. Given that the ICD may function as a weir or as an orifice, contingent upon the depth of available head, and that the capacity of the ICD is also contingent upon the depth of available head; proper sizing may require reasonable assumptions to be made.

For the purposes of design, the ICD shall be sized to accommodate the 1 in 5 year design flow under its maximum available head. For the purpose of design, the maximum available head shall be considered to be the depth from the top of the catchbasin grate to the ICD plus the additional 150 mm of depth that is allowed to flow in the gutter during a major storm event. It shall be noted that restricting flow into the minor storm system and diverting it to the major storm system shall be considered in the design and sizing of the major storm system.

A number of proprietary ICD designs and suppliers are available. However, the Consultant may propose an alternative design and sizing complete with supporting calculations, material and construction specifications for consideration.

In the case of a circular ICD design, when the maximum available head (*H*) exceeds 1.5 times the orifice diameter (*D*), the orifice equation may be used to determine the correct orifice diameter for the 1 in 5 year design flow given the maximum available head.

$$Q = C \cdot A \cdot \sqrt{2 \cdot g \cdot (H - r)} \quad \text{[C.1]}$$

where:

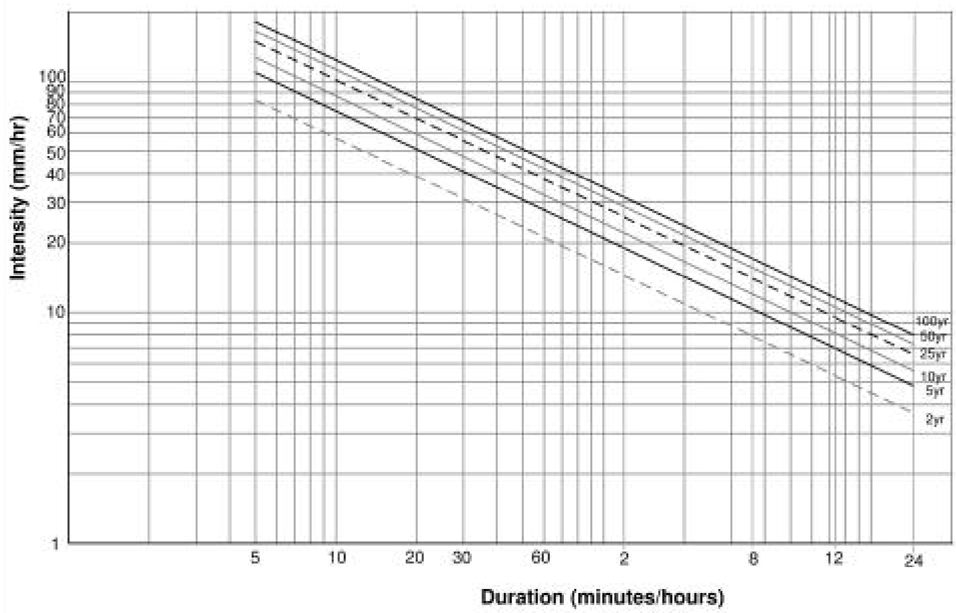
Q = capacity (m^3/s)
C = discharge coefficient (C=0.6)
A = open area (m^2)
g = gravitational acceleration (9.806 m/s^2)
H = head above invert (m)
r = radius (m)

APPENDIX D – Meteorological Data

FIGURE D.1

ANNUAL RAINFALL INTENSITY-DURATION-FREQUENCY CURVES FOR SAINT JOHN, NEW BRUNSWICK

BASED ON ENVIRONMENT CANADA ATMOSPHERIC ENVIRONMENT SERVICE DATA 1958-1994



	A	B
2yr	21.2	-0.552
5yr	27.8	-0.552
10yr	32.3	-0.552
25yr	37.9	-0.552
50yr	42.0	-0.552
100yr	46.1	-0.552

FIGURE D.2

2 HOUR DURATION CHICAGO DISTRIBUTION STORM - 1 IN 5 YEAR RETURN PERIOD

ANNUAL HYETOGRAPH FOR SAINT JOHN, NEW BRUNSWICK
BASED ON ENVIRONMENT CANADA ATMOSPHERIC ENVIRONMENT SERVICE DATA 1958-1994

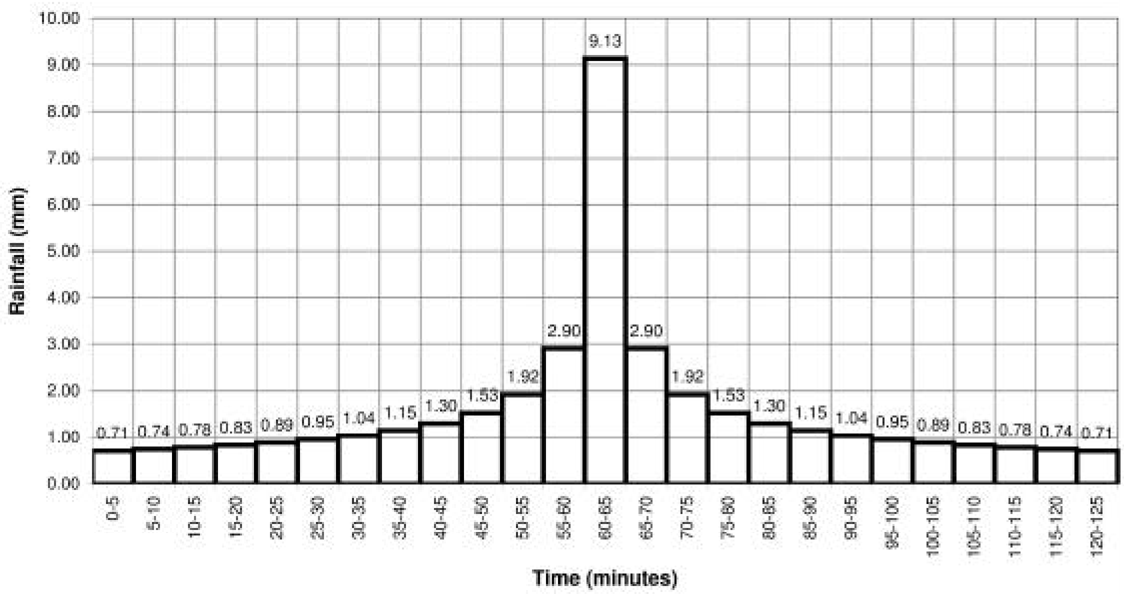


FIGURE D.3

2 HOUR DURATION CHICAGO DISTRIBUTION STORM - 1 IN 100 YEAR RETURN PERIOD

ANNUAL HYETOGRAPH FOR SAINT JOHN, NEW BRUNSWICK
BASED ON ENVIRONMENT CANADA ATMOSPHERIC ENVIRONMENT SERVICE DATA 1958-1994

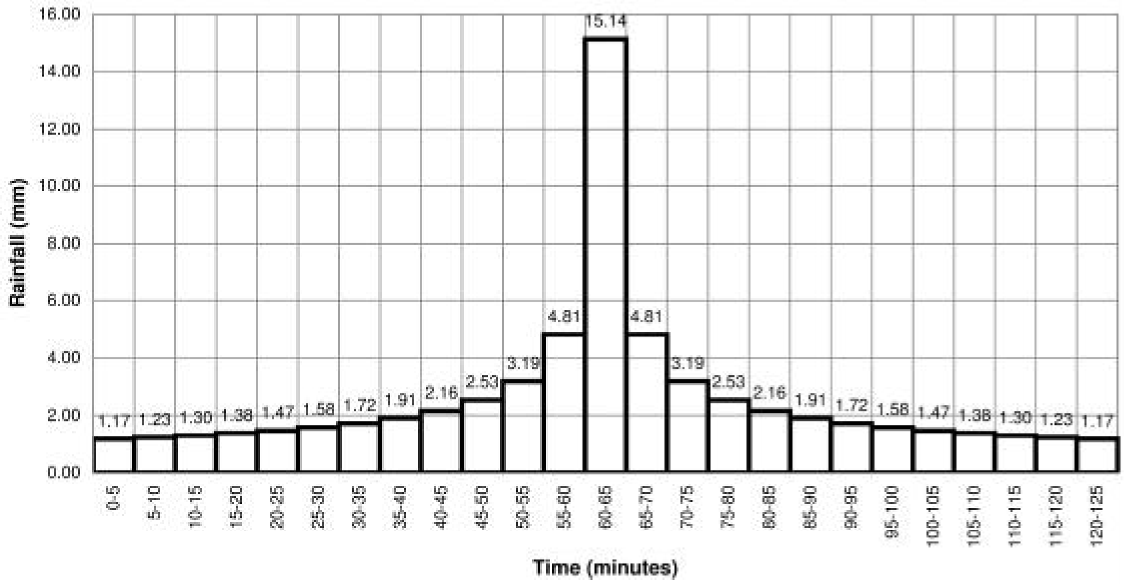


FIGURE D.4

24 HOUR DURATION CHICAGO DISTRIBUTION STORM - 1 IN 5 YEAR RETURN PERIOD

ANNUAL HYETOGRAPH FOR SAINT JOHN, NEW BRUNSWICK
BASED ON ENVIRONMENT CANADA ATMOSPHERIC ENVIRONMENT SERVICE DATA 1958-1994

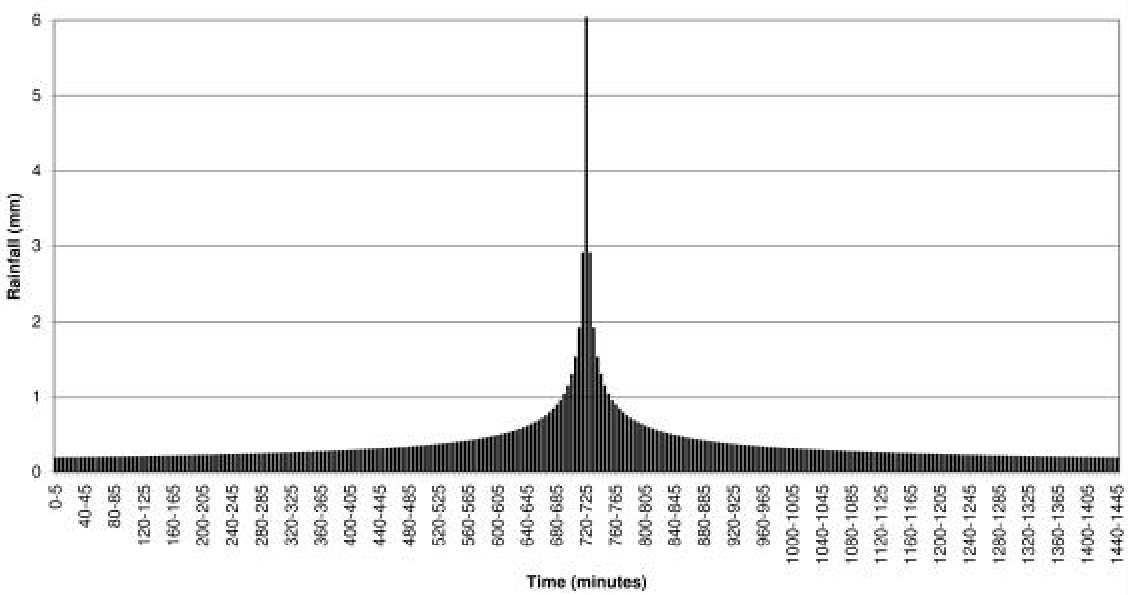


FIGURE D.5

24 HOUR DURATION CHICAGO DISTRIBUTION STORM - 1 IN 100 YEAR RETURN PERIOD

ANNUAL HYETOGRAPH FOR SAINT JOHN, NEW BRUNSWICK
BASED ON ENVIRONMENT CANADA ATMOSPHERIC ENVIRONMENT SERVICE DATA 1958-1994

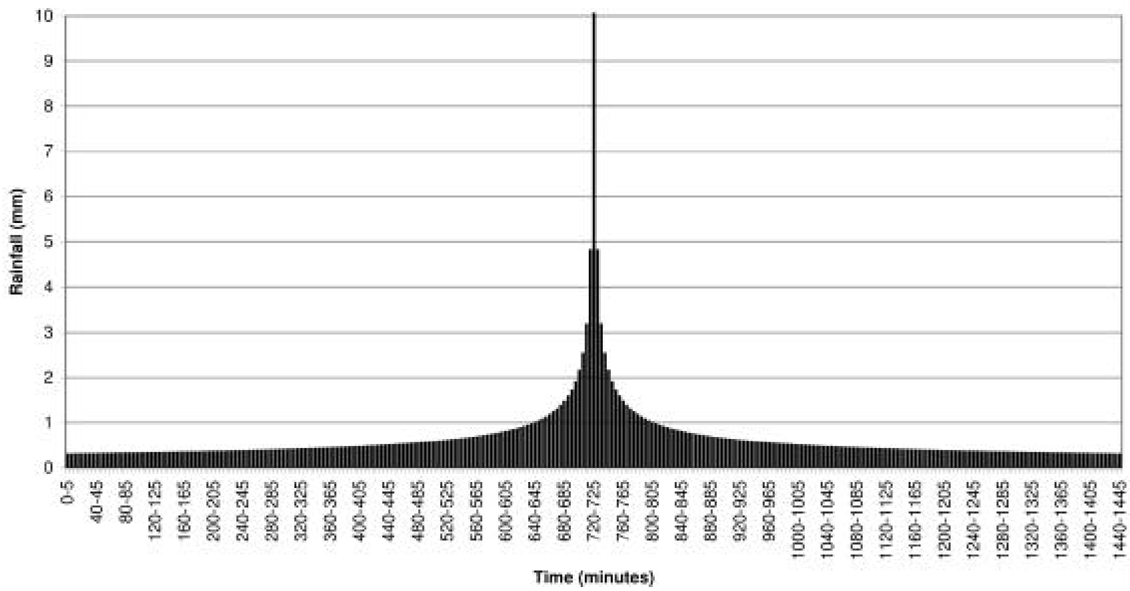


FIGURE D.6

ANNUAL WINTER RAINFALL INTENSITY-DURATION-FREQUENCY CURVES FOR SAINT JOHN, NEW BRUNSWICK

BASED ON ENVIRONMENT CANADA ATMOSPHERIC ENVIRONMENT SERVICE DATA 1958-1994
ADJUSTED BASED ON ENVIRONMENT CANADA RAINFALL FREQUENCY ATLAS
(SECTION 7.1 - PRECIPITATION EXTREMES DURING THE COLD SEASON)