HAMPTON
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Town of Hampton

STORMWATER MANAGEMENT GUIDELINES

October 2015

Submitted by

DILLON CONSULTING

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1. INTRODUCTION

1.1. Background

Urban development alters hydrologic characteristics though changes in land use, topography, and drainage. These changes result in reduced rates of infiltration and evapotranspiration, together with increased peak flows and runoff volumes. The impacts of urbanization include an increased risk of flooding, stream bank erosion, and degraded water quality.

Stormwater management provides a comprehensive approach to the planning, design and implementation of various techniques and practices aimed at providing practical and cost-effective methods to mitigate the impacts of development. The objectives of stormwater management include:

- Improve the quality of stormwater runoff;
- Reduce the rate and volume of runoff from developed areas;
- Ensure that the potential for flooding of downstream does not increase;
- Recharge existing aquifers;
- Maintain stream channel stability for receiving watercourses; and
- Maintain an appropriate diversity of aquatic life and opportunities for human uses.

1.2. Definitions

Designer:	An engineer or engineering firm currently licensed to practice within the Province of New Brunswick.
Developer:	The owner of the land proposed for development.
Engineer:	Any designated engineer acting on behalf of the Town of Hampton.
1 in 5 Year Storm Event:	A storm that has a 20% chance of occurrence in any given year. The minor system is designed to accommodate the 1 in 5 year event.
1 in 100 Year Storm Event:	A storm that has a 1% chance of occurrence in any given year. The major system is designed to accommodate the 1 in 100 year event.
Post-Development	A site's ground cover and grading after development, as it relates to new or re-developed areas.
Pre-Development	A site's ground cover and grading prior to any development taking place, as it related to new or re-developed areas.
Stormwater Management:	A system of vegetative and structural measures that control the increased volume and rate of surface runoff caused by man-made changes to the land.
Town:	The Town of Hampton including all representatives.

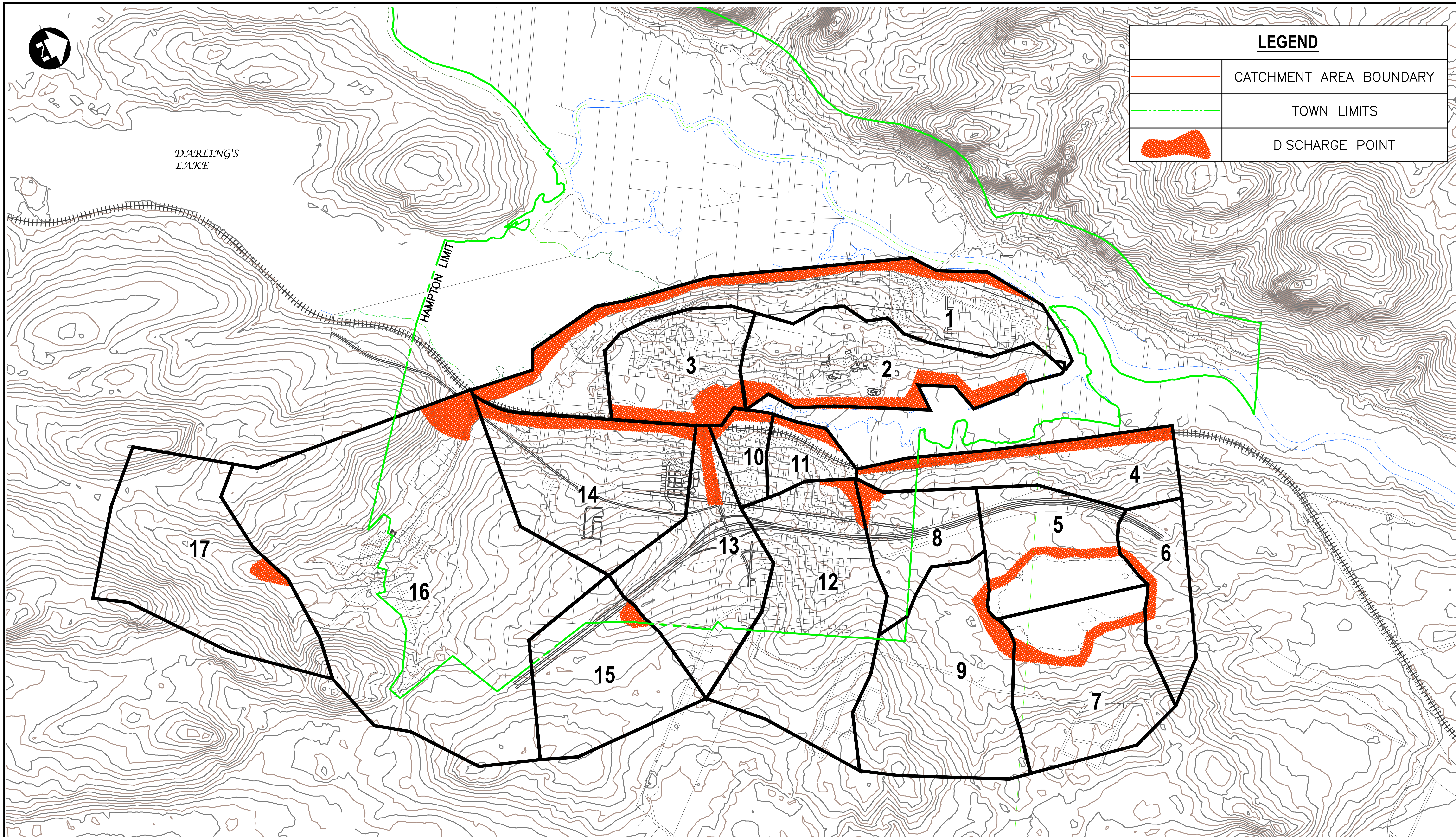
1.3. Existing Municipal Drainage System

The existing drainage system consists of a combination of sheet flow, open channels and culverts within the rural areas of the Town, together with a storm sewer network that services many of the roadways and adjacent areas in the central portion of the municipality. Runoff generated within the Town's boundaries ultimately flows into the Kennebecasis River via a series of outfalls and watercourses (Peters Brook, Ossekeag Creek, Grooms Brook, Ravine Brook, Pickwauket Brook, etc.).

The Town has been divided into multiple distinct sub-watersheds (refer to **Figures 1-4**). A summary of the hydrologic characteristics and drainage conditions within each of the sub-watersheds is provided in **Table 1** below.

Table 1. Local Subwatersheds

Sub-Watershed	Area (ha)	Land Uses	Drainage System	Receiving System
1	845.4	Wooded/Wetland/Residential	Ditch/Culvert	Kennebecasis River
2	217.5	Commercial/Wetland/Residential	Ditch/Culvert & Storm Sewer	Darlings Lake/Kennebecasis River
3	100.0	Wooded/Residential	Ditch/Culvert & Storm Sewer	Ossekeag Creek
4	146.0	Commercial/Wetland/Residential	Ditch/Culvert & Storm Sewer	Ossekeag Creek
5	170.2	Commercial/Wetland/Residential	Ditch/Culvert & Storm Sewer	Darlings Lake/Ossekeag Creek
6	28.5	Commercial/Wetland/Residential	Ditch/Culvert & Storm Sewer	Ossekeag Creek
7	32.5	Commercial/Wetland/Residential	Ditch/Culvert & Storm Sewer	Ossekeag Creek
8	104.9	Agricultural/Wooded/Residential	Ditch/Culvert	Ossekeag Creek
9	200.2	Wooded/Residential	Ditch/Culvert	Darlings Lake/Kennebecasis River
10	544.4	Wooded/Recreational/Residential	Ditch/Culvert	Darlings Lake/Kennebecasis River
11	141.1	Wooded/Residential/Commercial	Ditch/Culvert & Storm Sewer	Ossekeag Creek
12	213.7	Wooded/Residential	Ditch/Culvert & Storm Sewer	Peters Brook/Ossekeag Creek
13	74.5	Agricultural/Wooded	Ditch/Culvert	Peters Brook/Ossekeag Creek
14	110.4	Wooded		McManus Lake
15	64.4	Wooded		McManus Lake
16	135.5	Wooded		Ossekeag Creek
17	192.1	Wooded/Residential	Ditch/Culvert	McManus Lake
18	153.6	Wooded/Residential	Ditch/Culvert	McManus Lake



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PROJECT: TOWN OF HAMPTON STORM WATER MANAGEMENT

PROJECT NO. 13-7292

TITLE: CATCHMENT AREAS 1:40 000 (5m contours)

FIGURE NO. 1

DATE: AUGUST 31, 2015

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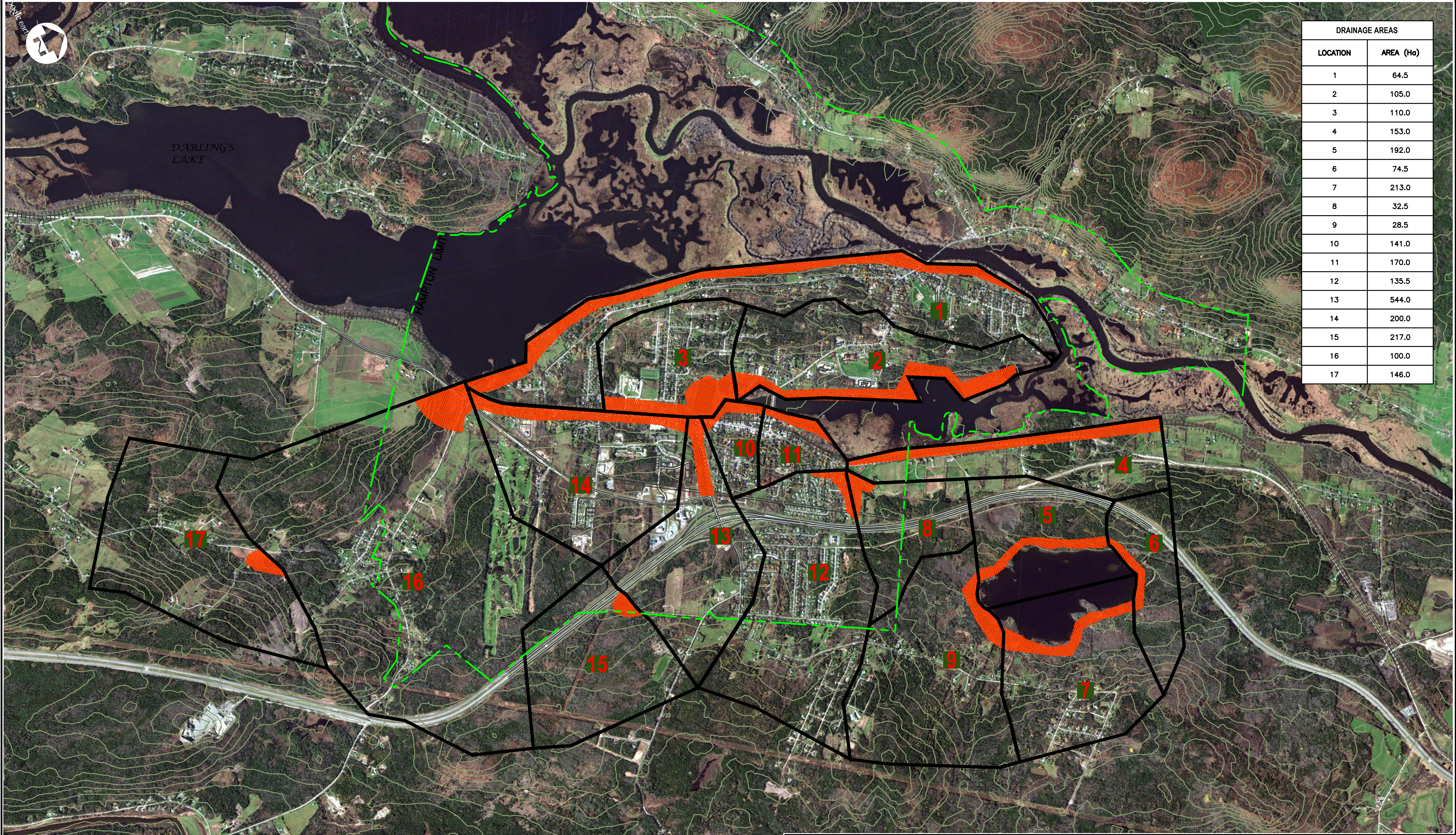

DRAINAGE AREAS	
LOCATION	AREA (Ha)
1	64.5
2	105.0
3	110.0
4	153.0
5	192.0
6	74.5
7	213.0
8	32.5
9	28.5
10	141.0
11	170.0
12	135.5
13	544.0
14	200.0
15	217.0
16	100.0
17	146.0

DILLON CONSULTING

DATE AUGUST 31, 2015

PROJECT: TOWN OF HAMPTON STORM WATER MANAGEMENT

TITLE: CATCHMENTS WITH AERIAL PHOTO 1:40 000 (5m CONTOURS)

PROJECT NO. 13-7292

FIGURE NO. 2

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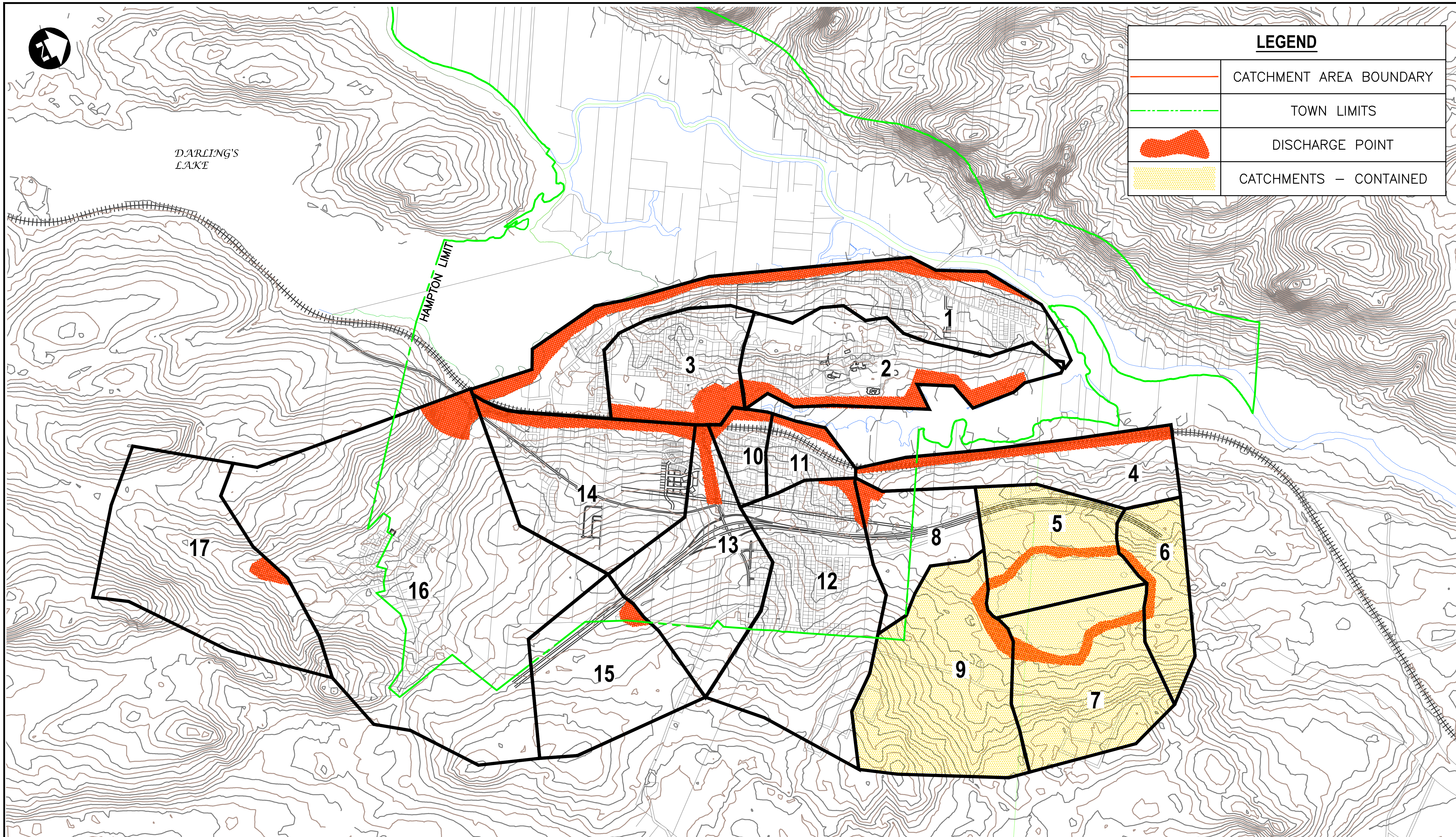

DILLON CONSULTING

PROJECT: TOWN OF HAMPTON STORM WATER MANAGEMENT

PROJECT NO. 13-7292

TITLE: CATCHMENTS - CONTAINED 1:40 000 (5m CONTOURS)

FIGURE NO. 3

DATE: AUGUST 31, 2015

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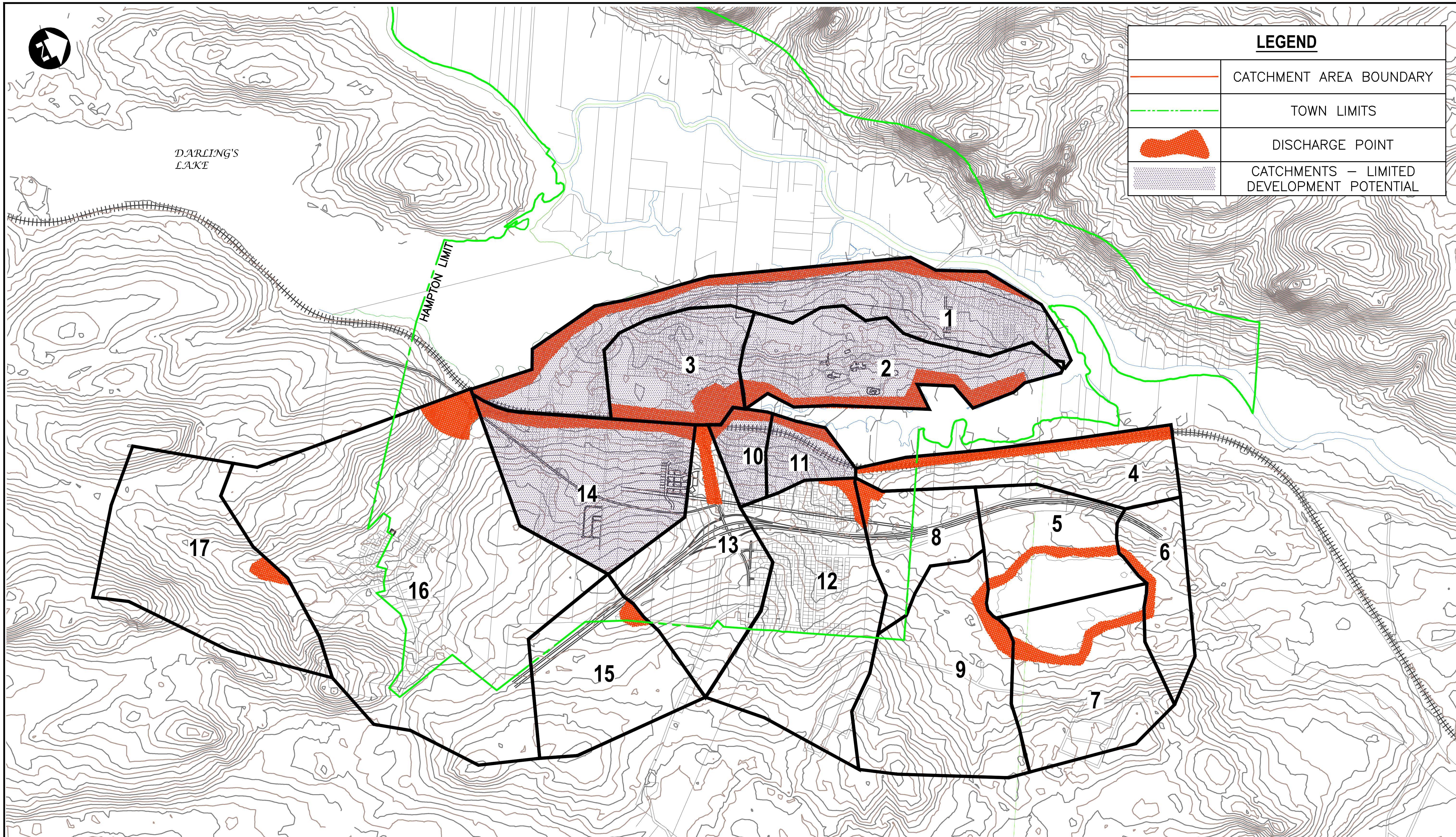

DILLON CONSULTING

PROJECT: **TOWN OF HAMPTON STORM WATER MANAGEMENT**

PROJECT NO. 13-7292

TITLE: **CATCHMENTS - LIMITED DEVELOPMENT POTENTIAL 1:40 000 (5m CONTOURS)**

FIGURE NO. 4

DATE: AUGUST 31, 2015

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1.4. Document Outline

The objective of the *Stormwater Management Guidelines* for the Town of Hampton is to provide uniform criteria and guidance for the planning, design and construction of municipal drainage infrastructure and stormwater management systems. An outline of the document is provided below.

- **Section 1** is an introduction to the document.
- **Section 2** describes the stormwater management planning framework.
- **Section 3** outlines the analytical methodologies that should be followed to assess existing and proposed drainage related infrastructure.
- **Section 4** provides a summary of typical hydrologic and hydraulic parameters;
- **Section 5** presents the prescribed design criteria that should be applied for the sizing of proposed drainage and stormwater management infrastructure;
- **Section 6 and Appendix A** provides a detailed description of best management practices (BMPs) for stormwater management infrastructure and erosion and sediment control measures, including benefits, design considerations, constraints and limitations, and operations and maintenance requirements.

2. STORMWATER MANAGEMENT PLANNING FRAMEWORK

Current stormwater management planning follows a comprehensive framework aimed at maintaining the overall health of the watershed by ensuring that changes in land use, ecological value, and drainage systems are implemented in a balanced and environmentally sustainable manner. An effective framework to stormwater management planning consists of a hierarchical approach that ranges from watershed scale assessments to site level design, as outlined below.

2.1. Watershed Plan

A watershed plan is intended for large study areas drained by major rivers (i.e., greater than 1000 km^2). The purpose of this planning tool is to integrate land use management and the protection of water resources, ecological integrity and other environmental considerations. To that end, a watershed plan is intended to identify environmental issues, constraints and sensitivities and outline a framework for technical analyses and investigations to be undertaken for subsequent studies.

2.2. Subwatershed Study

A subwatershed study typically considers areas of 50 to 200 km^2 and involves a comprehensive assessment of environmental conditions, including surface water resources, hydrogeology, water quality, geomorphology and aquatic and terrestrial resources. The primary purpose of these studies involves:

- Establishing goals and objectives to protect the health of the subwatershed;
- Define the existing environmental conditions within the subwatershed;
- Develop and evaluate alternative subwatershed management strategies;
- Identify the preferred strategy that best satisfies the established goals and objectives with respect to public acceptance, technical feasibility, cost, and environmental impacts; and
- Develop an implementation plan to guide the administration of the subwatershed plan.

2.3. Subdivision Drainage Plans

Subdivision or neighbourhood drainage plans involve the conceptual planning of the proposed drainage system that will service the proposed development. This includes the preliminary sizing and siting of infrastructure, functional assessment of the proposed drainage system, development of an overall stormwater management strategy, and an assessment of the receiving drainage environment.

2.4. Stormwater Management Report

A stormwater management report is required to support the design of drainage and stormwater management infrastructure for industrial/commercial/residential development. These typically include:

- A description of the methodology and results of technical analyses;
- Details regarding proposed stormwater management infrastructure, including location, layout, grading, outlet structure design, and hydraulic performance;
- Erosion and sediment control plans; and
- Operations and maintenance requirements and procedures.

2.5. Design Approach

The Town of Hampton aspires to work with developers while maintaining the overall health of the watershed.

It is the responsibility of the Developer to protect any and all downstream systems against flooding or aggravation caused by their proposed development.

The minor (piped) storm drainage system shall be designed to convey stormwater runoff generated by the 1 in 5 year return period storm. The major (overland) storm drainage system shall be designed to convey stormwater runoff generated by the 1 in 100 year return period storm. The major storm drainage system consists of: ditches, drainage channels, swales, curbed roadways, detention ponds, culverts and watercourses.

New developments are required to meet or exceed the following guidelines:

Figures 1 - 4 denote 18 catchments in and adjacent to the Town of Hampton. Each of the 18 catchments fall into three categories for future development, Potential, Limited and Contained. A summary of the development categories is provided in **Table 2** below.

Table 2. Catchment Areas

Catchment Areas					
Catchment 1	Potential	**Catchment 7**	Limited	**Catchment 13**	Potential
Catchment 2	Limited	**Catchment 8**	Potential	**Catchment 14**	Contained
Catchment 3	Limited	**Catchment 9**	Potential	**Catchment 15**	Contained
Catchment 4	Limited	**Catchment 10**	Potential	**Catchment 16**	Potential
Catchment 5	Limited	**Catchment 11**	Limited	**Catchment 17**	Contained
Catchment 6	Limited	**Catchment 12**	Potential	**Catchment 18**	Contained

Catchments noted as **Potential** have opportunity for future development. Developments in this area will be limited to the runoff generated in a pre-development 1 in 5 year 2 hour return period storm.

Catchments noted as **Contained** (noted on Figure 3) are on the border of the Town of Hampton. Developments in this area will be limited to the runoff generated in a pre-development 1 in 5 year 2 hours return period storm.

Catchments with **Limited** Development opportunities (noted on Figure 4) are restricted for all new potential development. Like other developments in the Town, developments in these areas will be limited to the runoff generated in a pre-development 1 in 5 year 2 hours return period storm.

Stormwater discharging from these areas must follow the following additional guidelines:

- If stormwater is to be discharged to Town infrastructure (including, but not limited to, swales, culverts, pipes), the Developer must assess the theoretical downstream capacities of the stormwater pipes until the post-development discharge rate of the proposed development or re-development (for storms up to and including the 1 in 100 year 24 hour event) is less than 10% of the available theoretical capacity. The developer must take into account the entire catchment area and all stormwater flows contributing to the piped networks. Record drawings will be available to the developer for their calculations and analysis. If record drawings are not available in the area needed, additional field investigations may be required to determine existing pipe sizes and slopes.
- When adequate downstream capacity does not exist, the developer must compensate by holding and/or retaining additional flows to meet the guideline as stated above. It is the responsibility of the Developer to mitigate effects of their development in the major and minor systems for any storm up to the 1 in 100 year 24 hour return period storm.

Please note: In cases where developments will have minimal additional runoff, will discharge directly to a watercourse or the 5 year 2 hour return period limitation is not reasonable, the Town is open to discussing alternative stormwater management that may differ from the requirements outlined in this document.

2.6. Submission Requirements

A developer proposing to develop or subdivide an area of land must submit to the Town for approval all plans, design memos and technical analyses required as outlined below.

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

- ✓ The Watershed Plan, Subwatershed Study, Subdivision Drainage Plan and/or the Stormwater Management Report as outlined above;
- ✓ Stamped Engineered development drawings; and
- ✓ A copy of the Engineering Design memo.

The Submission Package must include the following:

- ✓ Engineered Development Drawings showing the location of the proposed development. The plans must include the following;
    - o The location of the proposed development within the catchment drainage area (See Figure 1). This figure is available to the developer for submission with their stormwater management plan;
    - o Boundaries of catchment and subcatchment areas tributary to the proposed development including their associated pre and post-development runoff coefficients;
    - o All existing watercourses, ponds, swamps and wetlands (mapped or not);
    - o Site layout including proposed streets, lots and approximate location of proposed structures;
    - o Pre-development contours based on available mapping;

  - Post-development grading plan;
  - Location of any proposed storage facilities; and
  - Location of discharge points or connections to the existing systems, for both the minor and major storm drainage system.
- ✓ A description of the methodology and the results of the technical analyses. If assessment of downstream infrastructure was required, an outline of the investigation must be included. Any methods discussed in this document are acceptable;
- ✓ Details regarding proposed stormwater management infrastructure. Details to include location, layout, grading, outlet structure design, downstream impacts (and investigations) and hydraulic performance;
- ✓ Erosion and sediment control plans; and
- ✓ Operations and maintenance requirements and procedures.

3. ANALYTICAL METHODS

There are multiple analytical techniques and methodologies for carrying out hydrologic and hydraulic calculations, which are outlined below.

3.1. Hydrology

3.1.1. Rational Method

The Rational Method is an empirical equation for calculating the peak instantaneous flow for small watershed areas (i.e., < 20 ha). The peak flow is assumed to occur at a rainfall duration equal to the time of concentration for the subject watershed area (refer to **Section 4.3**)

$Q = 0.00278CIA$ where Q = peak flow (m^3/s)
C = runoff coefficient (refer to **Table 2**)
I = rainfall intensity (mm/hr)
A = drainage area (m^2)

3.1.2. SCS Curve Number Method

The Soil Conservation Service (SCS) Curve Number Method is a widely accepted technique for determining peak flows and runoff volumes for rural and suburban watersheds. The SCS method is a rainfall-runoff relationship that separates total rainfall into direct runoff, initial abstraction, and soil retention. Hydrologic soil groups and SCS Curve Numbers are summarized in **Table 3** and **4**, respectively. The SCS Curve Number Method is typically used in the development of hydrologic models, such as Visual OTTHYMO, HEC-HMS, OTTSWMM and SWMM. Hydrologic parameters are summarized

3.2. Hydraulics

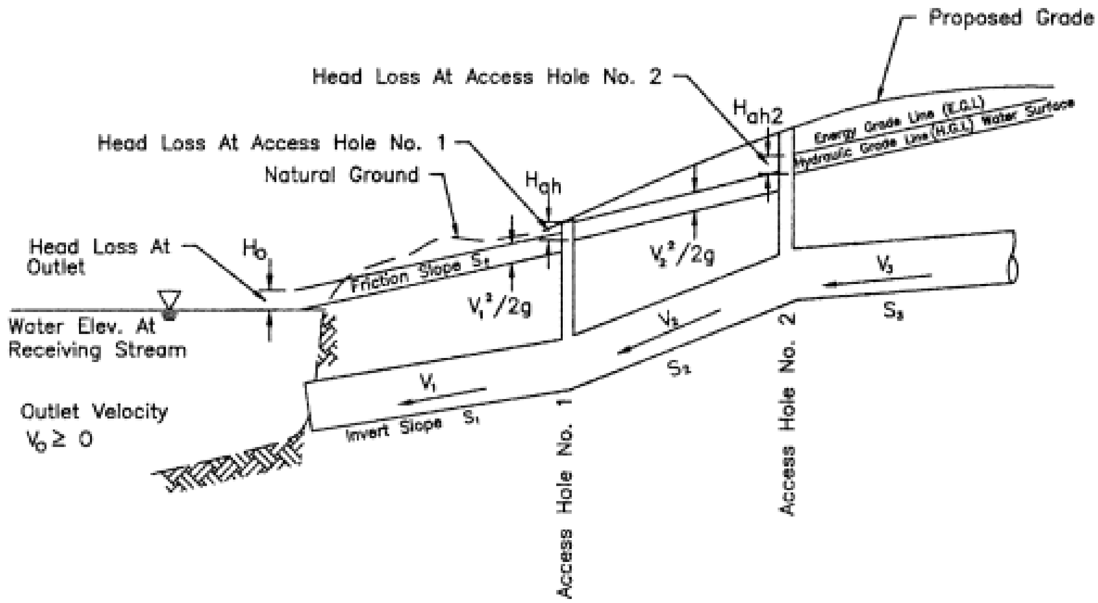
3.2.1. Manning Formula

The Manning Formula is an empirical relationship used to calculate open channel flow, including pipe systems (i.e., culverts, storm sewers, etc.) and open channels. The Manning Equation is provided below.

$Q = AR^{2/3}S^{1/2}/n$ where A = pipe cross-sectional area (m^2)
R = hydraulic radius (m)
S = slope (m/m)
n = Manning roughness coefficient (refer to **Table 5**)

3.2.2. Hydraulic Grade Line Analysis

The hydraulic grade line (HGL) analysis is a method for calculating water levels within a storm sewer system flowing under pressure. A graphical representation of the HGL within a storm sewer is shown on the figure below. The methodology and design parameters are outlined in the *HEC-22 Urban Drainage Design Manual* (US DOT, 2001).



Source: *HEC-22 Urban Drainage Design Manual* (US DOT, 2001).

3.2.3. HEC-RAS

HEC-RAS is a 1-dimensional hydraulic modeling software developed by the US Army Corps of Engineers. This program shall be used for the hydraulic analysis of open drainage systems, culverts and bridges in addition to the preparation of floodplain mapping.

4. HYDROLOGIC & HYDRAULIC PARAMETERS

4.1. Rainfall Data

Rainfall data is used in a variety of forms for the purpose of designing drainage and stormwater management infrastructure, including:

- *Intensity-Duration-Frequency Curve*

  Short duration rainfall IDF curves are developed by Environment Canada based on historical meteorological data measurements collected at a series of climate stations. The closest climate station to the Town of Hampton is the Saint John Airport (Station ID# 8104900). The IDF curve for this station is shown in **Figure 5**.

- *Synthetic Design Storm*

  Many synthetic storm distributions have been developed. The Chicago storm distribution should be applied for urban areas and the SCS Type 2 distribution should be used for the hydrologic analysis of rural watersheds.

- *Historical Design Storm*

  Measured rainfall data from extreme storms can be useful for analyzing the hydraulic performance of drainage systems and stormwater management facilities in the context of an historical event.

4.2. Runoff Coefficients

Applicable runoff coefficients for various land use conditions are provided in **Table 3** below.

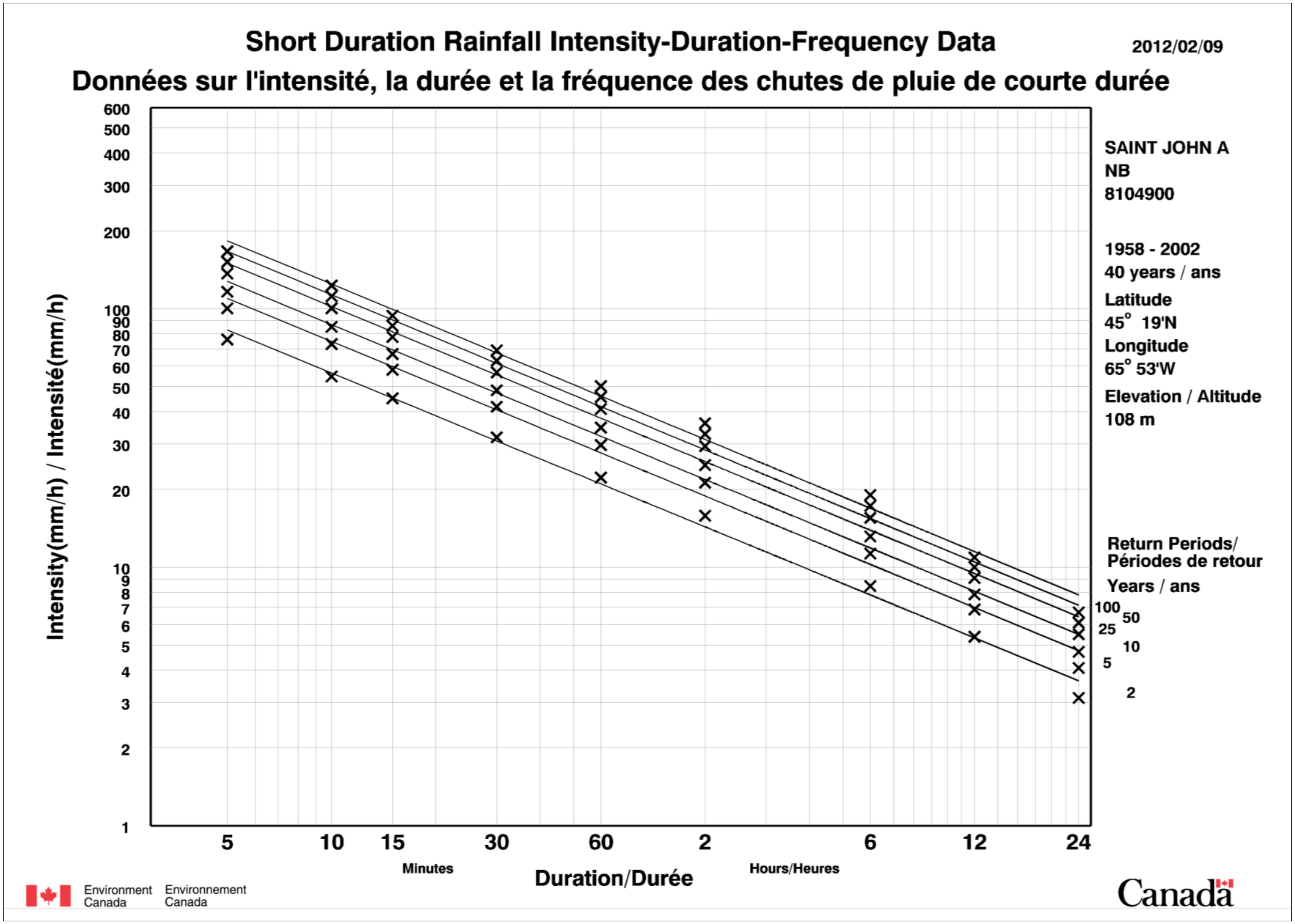
Table 3. Runoff Coefficients

Land Use	Description	Runoff Coefficient
Commercial	Downtown	0.70-0.95
	Neighbourhood	0.50-0.70
Industrial	Light	0.50-0.80
	Heavy	0.60-0.90
Residential	Single-Family	0.30-0.50
	Multi-Family	0.40-0.75
	Suburban	0.25-0.40
Open Space	Parks, Cemeteries, etc.	0.10-0.25

Source: *HEC22 – Urban Drainage Design (US Army Corps of Engineers, 2001)*

For winter conditions, a minimum runoff coefficient of 0.8 should be applied for all land use and surface cover conditions.

Figure 5. Short Duration IDF Curve for Saint John Airport



4.3. Hydrologic Soil Groups

Soils are classified into hydrologic soil groups (HSGs) based on the rate of infiltration and the corresponding runoff potential. A summary of the soil texture and runoff characteristics for each HSG is provided in **Table 4**.

Table 4. Hydrologic Soil Groups

Hydrologic Soil Group	Soil Texture	Description
A	Sand, loamy sand, sandy loam	High infiltration, low runoff potential
B	Silt loam or loam	Moderate infiltration/runoff potential
C	Sandy clay loam	Low infiltration, moderate runoff potential
D	Clay loam, silty clay loam, sandy/silty clay, clay	Very low infiltration, high runoff potential

Source: *TR-55 – Urban Hydrology for Small Watersheds (USDA, 1986)*

4.4. SCS Curve Numbers

Curve numbers for a wide range of land uses, surface cover materials and hydrologic soil groups are provided in **Table 5** below.

Table 5. SCS Curve Numbers

Land Use	Cover Type	Hydrologic Soil Group			
		A	B	C	D
Impervious	Paved Parking Lots, Roofs, Driveways, etc.	98	98	98	98
Streets & Roads	Paved (Curb & Storm Sewer)	98	98	98	98
	Paved (Open Ditches)	83	89	92	93
	Gravel	76	85	89	91
	Dirt	72	82	97	89
Residential	1/8 acre lots or less	77	85	90	92
	1/4 acre	61	75	83	87
	1/3 acre	57	72	81	86
	1/2 acre	54	70	80	85
	1 acre	51	68	79	84
	2 acres	46	65	77	82
Open Space	Poor Condition (Grass Cover < 50%)	68	79	86	89
	Fair Condition (Grass Cover 50-70%)	49	69	79	84
	Good Condition (Grass Cover > 75%)	39	61	74	80
Woods	Poor Condition	45	66	77	83
	Fair Condition	36	60	73	79
	Good Condition	30	55	70	77

Source: *TR-55 – Urban Hydrology for Small Watersheds (USDA, 1986)*

4.5. Hydraulic Characteristics

4.5.1. Friction Losses

Friction represents the most significant portion of the hydraulic losses experienced within a conduit. These losses are accounted for by the Manning roughness coefficient, which is determined based on pipe material. A summary of Manning roughness coefficients to be used for hydraulic calculations is provided in **Table 6**.

Table 6. Manning Roughness Coefficients

Material	Manning 'n'
PVC	0.011
Concrete	0.013
CSP	0.024

4.5.2. Minor Losses

In addition to friction, there are multiple minor hydraulic losses, including:

- Entrance losses;
- Junction (i.e., bend) losses;
- Transition (i.e., contraction/expansion) losses;
- Exit losses

Minor loss coefficients are summarized in the *HEC-22 Urban Drainage Design Manual* (US DOT, 2001).

5. DRAINAGE INFRASTRUCTURE DESIGN CRITERIA

5.1. Ditches

Roadside ditches shall be designed to convey the 1:100 year storm flow without flooding adjacent properties or roadways. Erosion protection should be provided in the form of riprap where velocities exceed 1 m/s.

5.2. Culverts

Culverts shall be sized to convey the applicable design flow under both inlet and outlet control conditions. The maximum headwater elevation (HW) at the inlet cannot exceed a HW/diameter ratio of 1. Further design requirements are summarized below.

- Minimum diameter = 375 mm;
- Driveway culverts to accommodate 1:5 year storm flows;
- Roadway cross culverts to accommodate 1:100 year storm flows; and
- A riprap apron is required at the outlet if the velocity > 1 m/s.

5.3. Storm Sewers

Storm sewers shall be designed to convey the flows generated by a 1:5 year return period storm. Analysis of the hydraulic performance of the storm sewer system must be undertaken to confirm that sufficient capacity is provided. A hydraulic grade line (HGL) analysis shall be completed that will account for minor and major losses (refer to **Section 5.5**).

- Minimum velocity = 0.6 m/s (for self-cleaning of pipes);
- Maximum velocity = 5.0 m/s (to reduce pipe thrust and scour);
- Minimum diameter = 300 mm;
- Minimum slope = 0.5%;
- Minimum depth = 1.2 m (to pipe obvert);
- Manholes must be installed in all locations where there is a change in pipe size, direction, vertical alignment and at pipe ends and intersections;
- Maximum manhole spacing = 120 m; and
- Minimum manhole diameter = 1,050 mm.
- Piped storm networks are to include a catch basin uphill of each driveway.

5.4. Roadway Conveyance

For curb and gutter systems, flows that cannot be conveyed by the storm sewer are to be conveyed along the roadway. Under these conditions, flows generated by a 1:100 year storm should be contained within the road right-of-way and discharged to open watercourses or designated overland flow routes.

5.5. Detention Ponds

Detention ponds provide an effective means of attenuating peak flows for large drainage areas (i.e., > 5 ha). These facilities shall be sized and configured to maintain post-development peak flows at pre-development levels for the subject development area. Additional design criteria for ponds include:

- Maximum depth = 2 m;
- Maximum side slopes = 4:1;
- Minimum freeboard = 300 mm;
- Wet ponds should include a minimum permanent pool depth of 1 m;
- The outlet shall consist of a headwall structure with a trash rack or approved equal;
- A riprap apron is required at the outlet for erosion protection; and
- A riprap lined emergency spillway must be incorporated at the outlet.

Please note: The Town of Hampton encourages partnerships to enhance, rehabilitate and improve the aesthetics of any proposed detention ponds.

6. STORMWATER BEST MANAGEMENT PRACTICES

In general, the recommended approach to stormwater management involves an integrated system comprised of lot level controls, conveyance measures, and end-of-pipe detention facilities. The advantages of an interconnected combination of innovative best management practices (BMPs) include:

- The ability to achieve a wide range of stormwater management goals and objectives;
- Reduced land area requirements for community detention systems;
- Lower life-cycle (i.e., construction and maintenance) costs; and
- Opportunities to create attractive public features that promote neighbourhood revitalization, recreational amenities, and public awareness related to the importance of managing water resources.

It is essential that planning for stormwater management is undertaken as early as possible in the development process to maximize the resulting benefits. An effective combination of suitable stormwater management controls will ensure that:

i) Water quality is protected;
ii) The potential for flooding does not increase;
iii) Watercourses will not undergo undesirable geomorphic change;
iv) Groundwater and baseflow characteristics are preserved; and
v) An appropriate diversity of aquatic life and opportunities for human uses will be maintained.

A description of conveyance measures and end-of-pipe detention facilities is provided in **Appendix A**, including typical benefits, design considerations, physical constraints and limitations, and operations and maintenance requirements.

A description of Best Management Practices for lot level controls is provided in **Appendix B**.

Table 7. Summary of Stormwater Management Practices

Type of Control	Physical Criteria	Effectiveness			
		Water Quality Control	Water Quantity Control	Erosion Control	Water Balance
Source/Lot Level Controls					
Rainwater harvesting	• None	✓	✓	✓	✓
Reduced lot grading	• Topography < 5% • Min. infiltration rate ≥ 15 mm/hr	✓	✓	✓	✓
Permeable pavement	• Topography < 5% • Min. infiltration rate ≥ 15 mm/hr • Groundwater > 1 m below bottom		✓	✓	✓
Bioretention areas	• Area ≤ 0.8 ha • Topography < 5% • Groundwater > 1 m below bottom	✓		✓	✓
Soakaway pits	• Area < 0.5 ha • Min. infiltration rate ≥ 15 mm/hr • Bedrock > 1 m below bottom • Groundwater > 1 m below bottom	✓	✓	✓	✓
Infiltration basins, chamber & trenches	• Min. infiltration rate ≥ 60 mm/hr • Bedrock > 1 m below bottom • Groundwater > 1 m below bottom	✓	✓	✓	✓
Oil-grit separators	• None	✓			
Conveyance Systems					
Grassed swales	• Area < 2 ha • Topography < 5%	✓		✓	✓
Bio-infiltration systems	• Area < 2 ha • Topography < 5% • Groundwater > 1 m below bottom • Min. infiltration rate ≥ 15 mm/hr	✓		✓	✓
End-of-Pipe Facilities					
Dry pond	• Area > 5 ha		✓	✓	
Wet pond	• Area > 5 ha	✓	✓	✓	
Constructed wetland	• Area > 5 ha	✓	✓	✓	

Note: Information obtained from the Low Impact Development Manual (CVC & TRCA, 2010), Stormwater Management Planning and Design Manual (MOEE, 1994), and Rapid Watershed Planning Handbook: A Comprehensive Guide for Managing UrbanizingWatersheds (CWP, 1998).

Appendix A

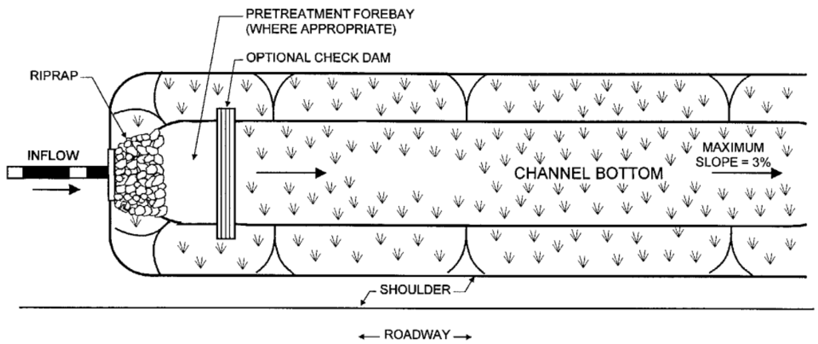
Stormwater Best Management Practices

Appendix A - Table of Contents

1.1. Conveyance Measures

1.1.1. Vegetated Swales

Swales are wide, shallow, gently sloped channels with a vegetated base and side slopes used to convey stormwater runoff. These linear drainage facilities are typically constructed along residential lot lines, and adjacent to roadways and parking lots.



***Source**: Center for Watershed Protection (1997)*

Benefits:

- Water quality enhancement;
- Increased infiltration and groundwater recharge;
- Reduces peak flows to receiving drainage infrastructure and/or watercourses;
- Provides volume control and maintains water balance by promoting infiltration.

Design Considerations:

i) Use Manning Equation for open channels to design swale for given flow conditions;
ii) Minimum bottom width of 1 m;
iii) Side slopes of 3:1 or less;
iv) Minimum freeboard of 150 mm;
v) Longitudinal slope should not exceed 2.5%;
vi) Soils should consist of sandy loam topsoil layer with less than 20% organic content;
vii) Vegetation should consist of drought tolerant species.

Physical Constraints & Limitations:

- Grassed swales are intended to service small drainage areas (i.e., < 2 ha) with imperviousness level no more than 35%;
- Not intended for areas with steep topography;
- Not effective for high velocity conditions.

O&M Requirements:

- Regular mowing of grass during growing season (e.g., bi-weekly);
- Remove debris and trash periodically;
- Remove accumulated sediment when build-up occurs;
- Re-seed areas of exposed soil or erosion.

1.1.2. Bio-Infiltration Systems

Bio-infiltration systems generally consist of vegetated infiltration facilities or rain gardens. These systems temporarily store, infiltrate and treat stormwater runoff. The primary component of a bio-infiltration system is the filter material that forms the base, which is comprised of a mixture of sand, fines and organic matter. Bio-infiltration systems are ideal for residential properties, along roadways, and adjacent to parking lots.

Benefits:

- Water quality enhancement;
- Increased infiltration and groundwater recharge;
- Reduces peak flows to receiving drainage infrastructure and/or watercourses;
- Provides volume control and maintains water balance by promoting infiltration.

Design Considerations:

i) Bottom width to be 0.75 – 3 m;
ii) Side slopes no steeper than 3:1;
iii) Gravel storage should consist of minimum of 300 m depth of 50 mm clear stone;
iv) Filter media should include mixture of approximately 85% sand, 10% fines, 5% organic material;
v) Perforated sub-drain recommended where native soil infiltration rate < 15 mm/hr.

Physical Constraints & Limitations:

- Bio-infiltration systems are intended to service small drainage areas (i.e., < 2 ha);
- Minimum depth to groundwater table is 1 m;
- Minimum infiltration rate of 15 mm/hr;
- Not intended for areas with steep topography.

O&M Requirements:

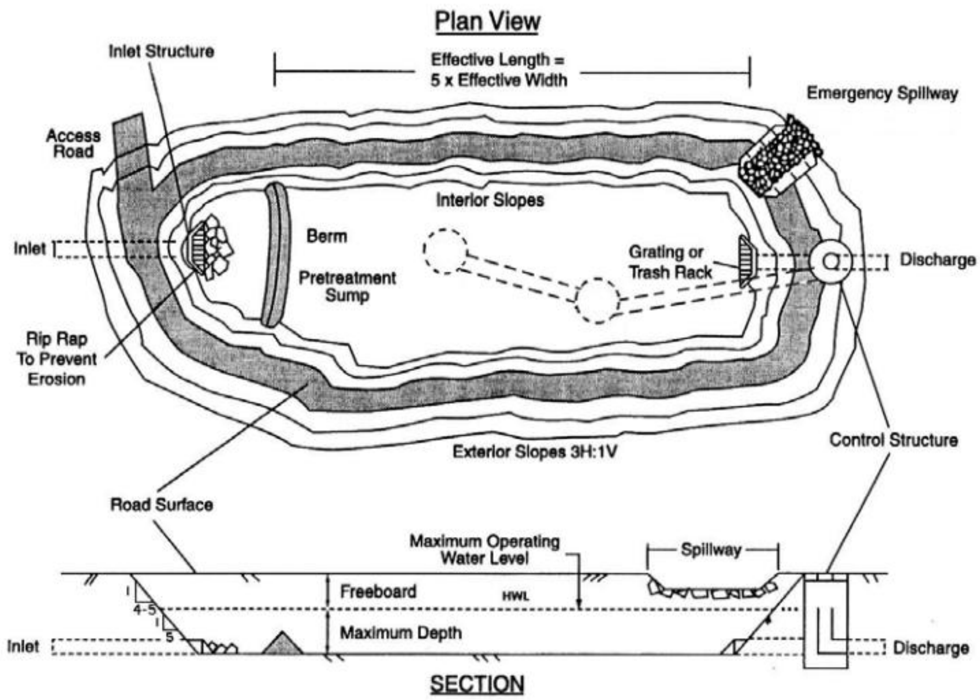
- Remove debris and trash periodically;
- Remove accumulated sediment when build-up occurs.

1.2. Community Detention Systems

Detention ponds provide an effective means of managing stormwater runoff from moderate to large drainage areas (i.e., > 5 ha). These include dry ponds, wet ponds, and constructed wetlands, which are described below.

1.2.1. Dry Ponds

Dry ponds are impoundment areas that are used to temporarily detain stormwater for the purpose of reducing the risk of flooding and erosion of downstream drainage infrastructure. These facilities can be designed as multi-purpose features, such as vegetated open spaces or recreational areas.



Source: *City of Calgary Stormwater Management and Design Manual (2011)*

Benefits:

- Peak flow attenuation;
- Increased infiltration and groundwater recharge;
- Limited water quality enhancement.

Design Considerations:

i) Size pond based on design objectives for flood control and/or streambank erosion;
ii) Side slopes should not exceed 4:1 for public safety;
iii) Incorporate forebay for removal of course sediment;
iv) Minimum length to width ratio of 2:1 (4:1 preferred);
v) Include a minimum 300 mm freeboard allowance;
vi) Provide emergency overflow spillway to convey flows that exceed pond design storm.

Physical Constraints & Limitations:

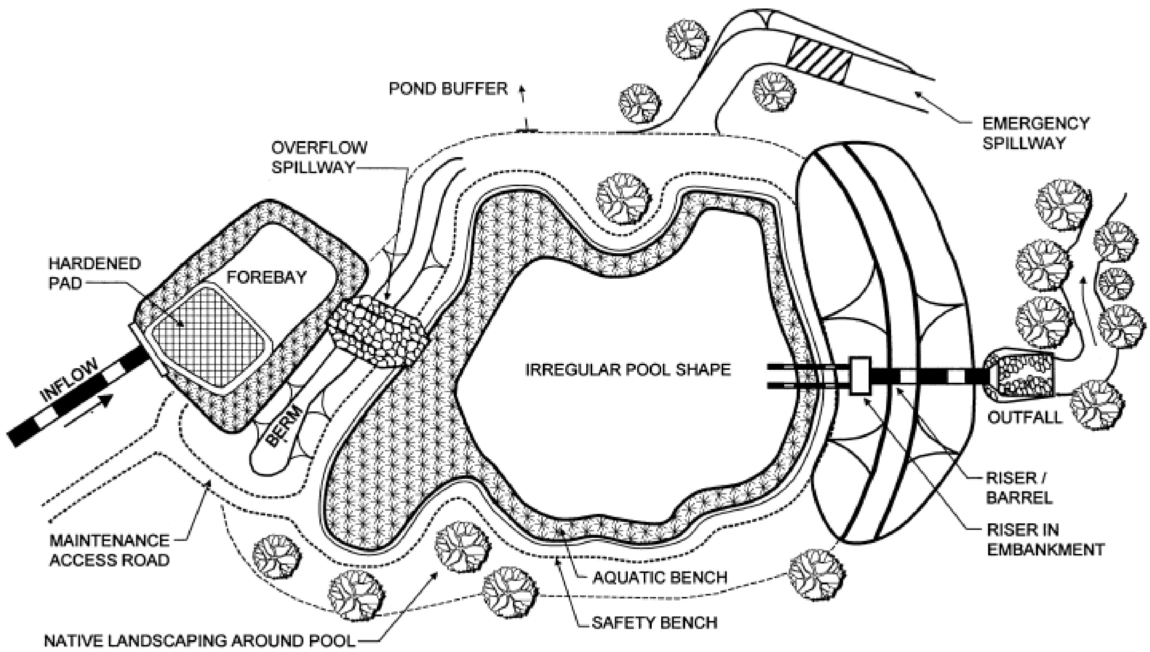
- Not intended for small catchment areas (i.e., < 5 ha);
- Outlet structures may get clogged with trash and debris – periodic inspection is recommended;
- Minimal water quality enhancement.

O&M Requirements:

- Periodic sediment removal;
- Inspection of outlet for trash/debris clogging;
- Grass mowing and landscaping.

1.2.2. Wet Ponds

Wet ponds are designed to provide water quality treatment in addition to detaining collected runoff for flood control and streambank erosion. The permanent pool promotes the settlement of suspended solids and other urban runoff contaminants such as heavy metals, while the active volume component provides storage to attenuate flows for a specific storm return period. Wet ponds can serve multiple additional functions, including fish and wildlife habitat, recreational use and aesthetic improvements.



Source: *Centre for Watershed Protection (1997)*

<u>Benefits:</u>

- Flood control;
- Streambank erosion protection;
- Increased infiltration and groundwater recharge;
- Water quality treatment;
- Community enhancement.

<u>Design Considerations:</u>

i) Size pond based on design objectives for water quality treatment flood control and/or streambank erosion;
ii) Minimum permanent pool volume of 1 m;
iii) Side slopes should not exceed 4:1 and safety bench at permanent pool level unless perimeter fencing is installed;
iv) Incorporate forebay for removal of course sediment;
v) Minimum length to width ratio of 3:1 (4:1 preferred);
vi) Include a minimum 300 mm freeboard allowance;
vii) Provide emergency overflow spillway to convey flows that exceed pond design storm;

viii) Include maintenance access road.

Physical Constraints & Limitations:

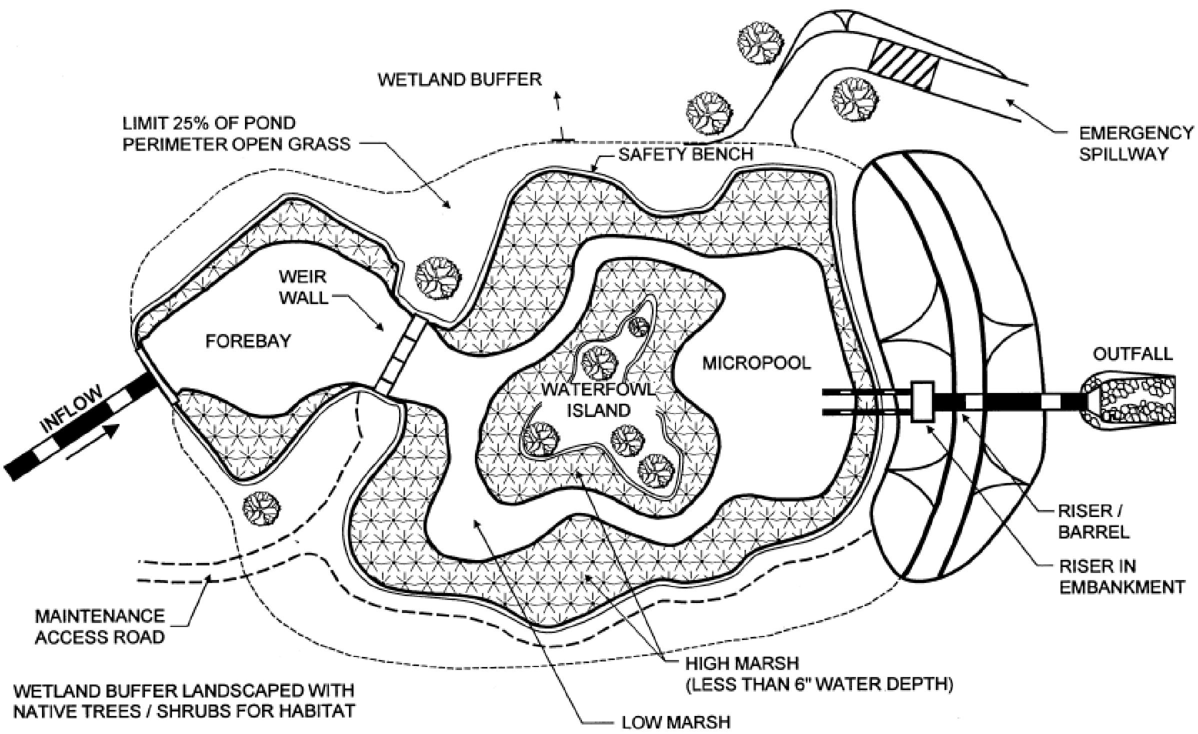
- Requires adequate contributing flows to maintain permanent pool;
- Not intended for small catchment areas (i.e., < 5 ha);
- Infiltration capacity based on native soil conditions;
- Outlet structures may get clogged with trash and debris – periodic inspection is recommended;
- Minimal water quality enhancement.

O&M Requirements

- Periodic inspection to observe hydraulic function;
- Removal of accumulated sediment;
- Inspection of outlet for trash/debris clogging;
- Control nuisance insects;
- Grass mowing and landscaping.

1.2.3. Constructed Wetlands

Engineered wetlands are similar in form and function as wet ponds, but can provide an enhanced water treatment capacity due to the added vegetation filtration and nutrient uptake. Design objectives must balance the stormwater benefits with the ecological function of the facility.



Source: *Centre for Watershed Protection (1997)*

<u>Benefits:</u>

- Flood control;
- Streambank erosion protection;
- Increased infiltration and groundwater recharge;
- Water quality treatment;
- Provides aquatic and terrestrial habitat;
- Community enhancement.

<u>Design Considerations:</u>

i) Size pond based on design objectives for water quality treatment flood control and/or streambank erosion;
ii) Minimum permanent pool volume of 0.3 m;
iii) Side slopes should not exceed 6:1 and safety bench at permanent pool level unless perimeter fencing is installed;
iv) Incorporate forebay for removal of course sediment;
v) Minimum length to width ratio of 3:1 (4:1 preferred);
vi) Include a minimum 300 mm freeboard allowance;

vii) Vegetation should be native and tolerant of wide ranges in water level, pH and temperature;
viii) Provide emergency overflow spillway to convey flows that exceed pond design storm;
ix) Include maintenance access road.

Physical Constraints & Limitations:

- Requires adequate contributing flows to maintain permanent pool;
- Not intended for small catchment areas (i.e., < 5 ha);
- Infiltration capacity based on native soil conditions;
- Outlet structures may get clogged with trash and debris – periodic inspection is recommended;
- Minimal water quality enhancement.

O&M Requirements

- Periodic inspection to observe hydraulic function;
- Removal of accumulated sediment;
- Inspection of outlet for trash/debris clogging;
- Control nuisance insects;
- Grass mowing and landscaping.

1.3. Erosion & Sediment Control

Erosion prevention is essential and is the most effective method in protecting downstream aquatic habitat during the construction process. Erosion controls involve minimizing the extent of disturbed areas by clearing only what needs to be cleared, preserving and protecting natural cover, and immediately stabilizing disturbed areas.

1.3.1. Vegetative Filter Strips

In an effort to limit the area of disturbance and resulting erosion potential, as well as trap sediment through filtration and improve infiltration capacity, strips of natural vegetation should be identified, marked and protected from the effects of construction activities. Vegetative filter strips are of particular importance along watercourses to reduce bank erosion and sediment loading.

Design considerations and specifications:

- Fence or flag clearing limits and keep all equipment and construction materials out of the natural areas;
- Keep all excavations outside of the dripline of trees and shrubs;
- Vegetative filter strips should be maintained along the top of bank of all watercourses (15 m wide adjacent to warm water streams and 30 m adjacent to cold water systems); and
- Additional ESC measures, such as silt fencing, may be required to prevent overloading of sediment to the filter strip, which can also act an additional barrier to prevent construction equipment from entering the area.

Inspection and maintenance requirements:

- Inspect area frequently to ensure that flagging or fencing remains in place and repair as required.

1.3.2. Stabilization

All areas exposed by construction activities for more than 7 days should be stabilized through the application of vegetative cover, through mechanical seeding or hydroseeding.

Design considerations and specifications:

- Seeding should be applied using mechanical equipment to ensure even seed application;
- If seeding is undertaken between November and March, mulching is required immediately after application to provide an immediate protection of exposed soils and aid in the establishment of vegetation;
- Fertilizer may be required to accelerate the establishment of vegetation;
- Re-seeding may be necessary if there are disturbed areas that do not respond to the initial application, as determined through inspection; and,
- The seed mixture that is applied is to consist of native, non-invasive species.

Inspection and maintenance requirements:

- Inspect areas that have been seeded on regular basis following application; and,
- Re-seed and fertilize areas that fail to establish vegetative cover.

1.3.3. Erosion Control Blankets

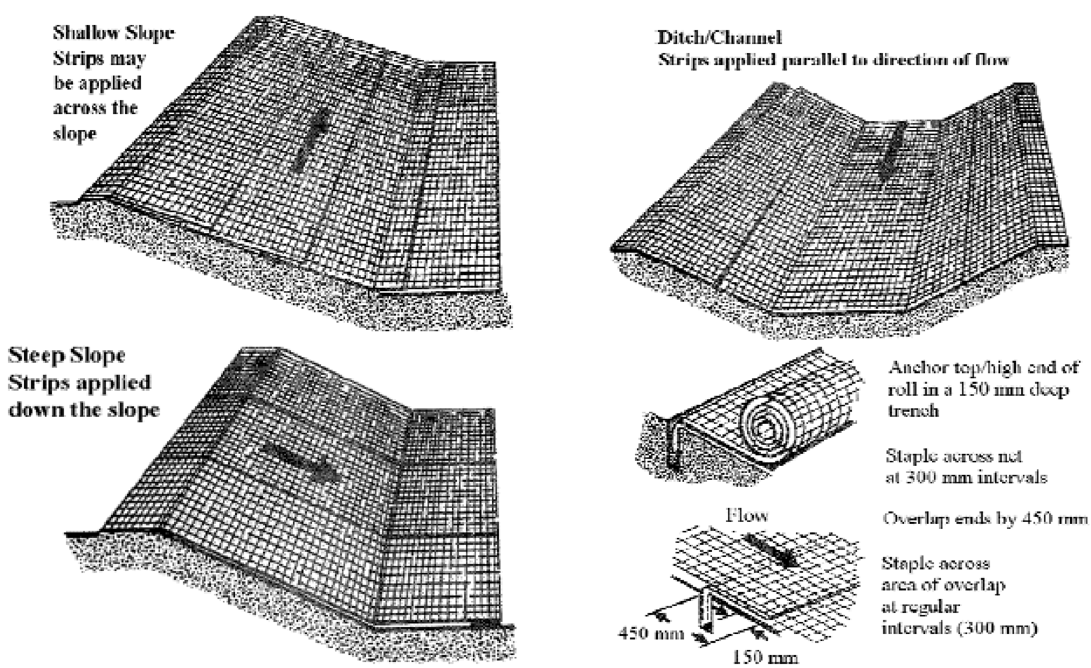
Erosion control blankets consist of prefabricated layers of material, generally biodegradable, which are laid on a soil surface to prevent erosion and promote seed growth. Application of this BMP is recommended in areas where the potential for erosion is greater (i.e., steep slopes, increased flows) and/or at locations where standard stabilization methods (e.g., seeding, mulching) are ineffective.

Design considerations and specifications:

- Apply to exposed slopes greater than 2H:1V and within conveyance systems (i.e., ditches, swales, etc.);
- Surfaces must be seeded (with or without mulch) prior to application;
- Firm, continuous contact between the blanket and soil is critical – rolling and stapling may be required following installation, and efforts should be made to ensure that all debris (i.e., rocks, branches, etc.) is removed from the surface; and
- The manufacturer's instructions/specifications must be followed regarding the selection of a suitable blanket type, overlap length, anchoring methods, etc.
- Orientation of the blankets should follow the direction of flow (i.e., vertically on slopes and horizontally along ditches and other watercourses (refer to figure below).

Inspection and maintenance requirements:

- Inspect periodically until vegetative cover is established, as well as following all significant rainfall events; and
- Repair all damaged areas immediately.



***Source**: Keeping Soil on Construction Sites (HRCA & HCA, 1994)*

1.3.4. Silt Fence

Perimeter controls are implemented to protect adjacent areas down-gradient from the construction site and/or divert sediment laden runoff away from unprotected/disturbed slopes and areas. Perimeter controls are also utilized to convey runoff from external drainage away from a construction site. Although some perimeter controls may provide some sedimentation, its main function is to prevent sediment laden runoff from encroaching onto adjacent undisturbed areas, unprotected slopes, and/or water courses.

The purpose of silt fencing is to intercept and detain suspended sediment travelling in the form of sheet flow off of disturbed areas. Silt fencing should be installed along the perimeter of sensitive or protected areas, along watercourse corridors and at the base of moderate to steep .

Silt fence consists of a non-woven synthetic geotextile fabric stretched across and attached to supporting post and wire fence. This measure does NOT filter runoff, but acts as a linear barrier creating upstream ponding which allows soil particles to settle out thereby reducing the amount of soil leaving a disturbed area. The sediment control fence also decreases the velocity of sheet flow and low to moderate level concentrated flows.

Design considerations and specifications:

- Posts are to be spaced no more than 1.8 m apart and driven into the ground a minimum of 750 mm, where possible;
- Posts shall be 50 mm x 50 mm wood stakes or equivalent;
- A trench must be excavated approximately 200 mm wide and 300 mm deep along the line of posts, on the upslope side of the barrier, and should follow the slope contour;
- Geotextile material should be woven type 270R or equivalent and, if possible, should be cut from a continuous roll to avoid joints – if joints are necessary, geotextile should be spliced only at support posts, with a minimum overlap of 200 mm and both ends secured to the post;
- When standard strength geotextile is used, a wire mesh support fence shall be fastened securely to the upslope side of the posts using heavy duty staples (i.e., 25 mm long), tie wires or hog rings – the wire must extend into the trench a minimum 50 mm and not more than 900 mm above the original ground surface;
- If extra-strength geotextile is used and post spacing is reduced, the requirement for a wire mesh support fence is eliminated; and,
- When sediment accumulates to half the height of the silt fence, it should be removed and replaced.

Inspection and maintenance requirements:

- Inspect after every significant rainfall event and daily during prolonged periods of rain;
- Ensure that base of geotextile remains buried and posts are anchored as shown on Figure 3; and,
- If sediment accumulates above one third of the height of the silt fence, remove or replace section of fence, if necessary.

1.3.5. Interceptor/Diversion Swales and Dykes

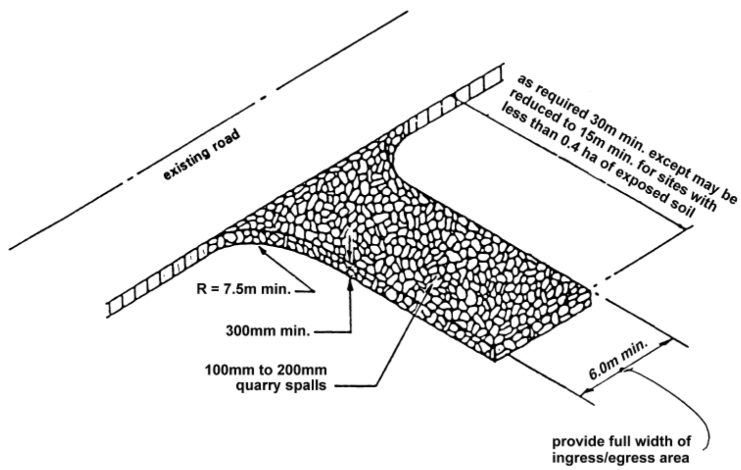
The purpose of interceptor/diversion swales and dykes is to divert runoff around disturbed areas to a stabilized outlet or location through the use of temporary grading of conveyance systems. A typical detail for an interceptor/diversion swales is provided on figure below.

Design considerations and specifications:

- Temporary interceptor/diversion swales and dykes should be constructed along the top of long or steep slopes (i.e., >3H:1V) or where the contributing drainage area exceeds 2 ha;
- Additional flow control should be provided through the installation of rock or straw bale check dams at appropriate intervals, if longitudinal slope is greater than 5%; and
- Swales should be stabilized through vegetation or rip-rap, where required to prevent erosion.

Inspection and maintenance requirements:

- Inspect periodically until vegetative cover is established, as well as following all significant rainfall events; and
- Repair all damaged areas immediately.



Source: Best Management Practices for Stormwater – Greater Vancouver Sewerage & Drainage District (Dayton & Knight, 1999)

1.3.6. Mud Mats at Construction Entrances

The purpose of mud mats is to provide a stabilized entrance for construction equipment in order to prevent the transport of sediment to nearby watercourses or sensitive features. A mud mat should be constructed at the entrance of all sites where the area of disturbance is greater than one ha, and/or will involve grading or filling activities in close proximity to the entrance (refer to figure below).

Design considerations and specifications:

- Stone pad must be a minimum of 20 m in length and the full width of the proposed entrance;
- The pad must be 300 – 450 mm thick, consisting of 50 mm diameter clear stone for the first 10 m (from entrance) and 150 mm diameter clear stone for the remainder, which is to be reasonably free of fine materials;
- The pad shall be underlain with a layer of geotextile; and
- In the case the entranceway crosses a ditch or other watercourse and requires the installation of a culvert, appropriate ESC measures should be implemented (e.g., silt fencing, inlet and outlet protection, rock or straw bale check dams).

Inspection and maintenance requirements:

- Inspect periodically and following all significant rainfall events to ensure that
- Repair as required.

1.3.7. Rock Check Dams

A rock check dam consists of granular material placed temporarily across a ditch, minor stream or drainage way. Its purpose is to reduce the velocity of runoff to reduce the erosion of ditch and drainage way inverts. Rock check dams allow for little ponding and are therefore not very effective in settling out sediment, particularly fine soil particles.

Rock check dams are to be installed in ditches where longitudinal slope exceeds 5% or where flow velocities are high enough to result in significant channel erosion. Although minimal, rock check dams also provide an opportunity for settlement of suspended solids through detention.

Design considerations and specifications:

- Check dams are to be constructed of appropriate sized rock (i.e., D50 = 150 mm), with bottom layer consisting of smaller stones to a height of 0.45 m and larger stones making up the top layer at a thickness of 0.15 m;
- A layer of non-woven geotextile is to be placed between the top and bottom layers and extended along the upstream end and anchored with additional stone;
- The rock should be placed with a maximum upstream slope of 2:1 and downstream slope of 4:1;
- A sump of 300 mm should be excavated upstream of each rock check dam; and,
- The maximum spacing between dams should be such that the toe of the upstream dam is a the same elevation as the top of the downstream dam.

Inspection and maintenance requirements:

- Inspect structures weekly and following significant rainfall events;
- Ensure that geotextile is properly anchored at upstream end;
- Place additional rock on dam if settling or movement of stones has occurred; and,
- Remove accumulated sediment when it accounts for half of the sump capacity and stabilize.

1.3.8. Sediment Traps

Sediment traps consist of small, temporary ponding areas that collect and detain runoff to facilitate the settlement of suspended sediment, prior to discharging from the site. Sediment traps can be constructed by excavating a basin or forming a perimeter containment berm, complete with an outlet lined with rock or equivalent material.

Design considerations and specifications:

- Structure should have a 450 mm (minimum) deep sump for storage of sediment;
- Side slopes should not exceed 3:1;
- The trap should be designed to accommodate a 2-year, 24-hour rainfall event; and
- The length to width ratio should be approximately 3:1.

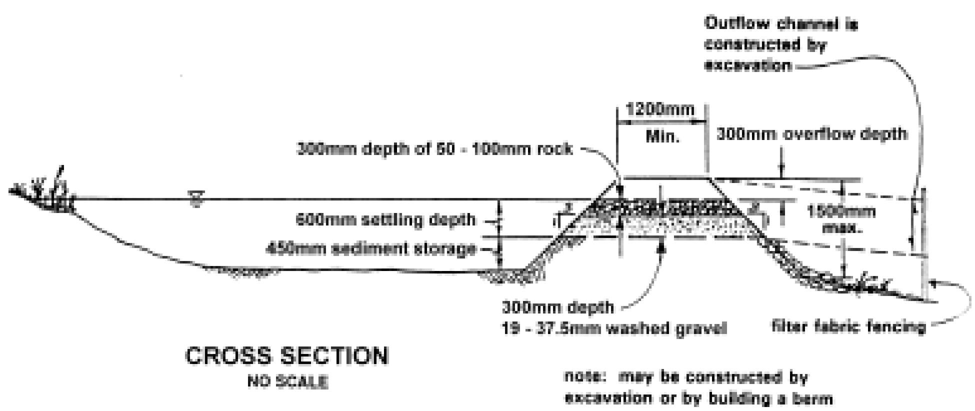
Inspection and maintenance requirements:

- Inspect structures weekly as well as during and following significant rainfall events;
- Remove accumulated sediment when it reaches a depth of 300 mm and stabilize on-site by seeding to promote vegetation; and,
- Ensure that spillway is functioning as intended and repair if necessary.

1.3.9. Storm Drain Inlet Protection

Storm Drain Inlet Protection consists of a sediment control barrier (filter fabric) either around or in the catchbasin inlet. The inlet protection filters runoff before it is released to the sewer system. rain/sewer inlet protection reduces the amount of sediment entering the storm drainage system prior to the permanent stabilization of disturbed areas.

As an alternative to the above, Inletsoxx™ or straw waddles can be used a physical barrier that reduces the rate at which sediment-laden water can enter the storm or tile drain system.



Source: Best Management Practices for Stormwater – Greater Vancouver Sewerage & Drainage District (Dayton & Knight, 1999)

1.3.10. Sediment Bags

Sediment Bags consist of UV stabilized, geotextile material sewn into a rectangular bag structure and are used to filter out suspended sediment from dewatering discharge (refer to photo). For smaller sites, sediment bags are often a more economic and effective method of filtering sediment laden waters than sediment basins or ponds.

Source: *Pennsylvania Groundwater Association*

Appendix B

Lot Level - Best Management Practices

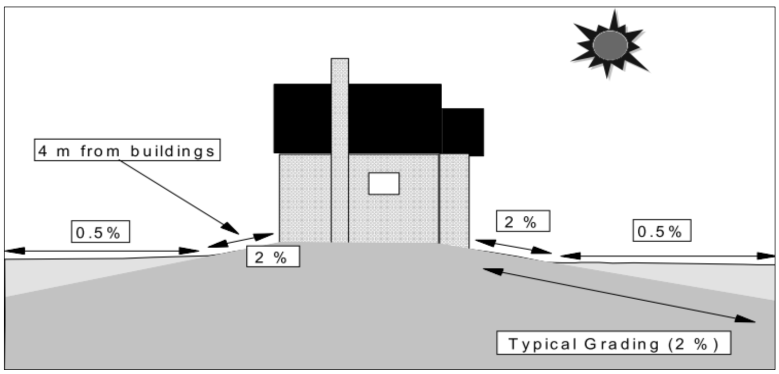
Appendix B – Table of Contents

1.1. Lot Level Controls

These controls are implemented at a lot level for the purpose of maintaining pre-development hydrologic characteristics to the extent possible, through on-site storage and infiltration systems aimed at attenuating peak flows and minimizing runoff volume.

1.1.1. Reduced Lot Grading

By reducing grades on individual lots, infiltration of surface runoff is promoted, thereby decreasing flows directed to the receiving drainage system. Although minimum grades are necessary to provide positive drainage conditions away from houses and other structures (typically 2%), it is recommended that lot grades are reduced to 0.5 – 2%, where practical.



***Source**: MOE, 2013*

Benefits:

- Reduces peak flows to receiving drainage infrastructure and/or watercourses.
- Provides volume control and maintains water balance by promoting infiltration.
- Reduces end-of-pipe facility requirements and the associated land needs.

Design Considerations:

i) A minimum 300 mm of topsoil should be applied
ii) The grading within 2 – 4 m of houses and other structures should be a minimum of 2% to avoid foundation drainage issues.
iii) Depressional areas outside of setback from houses are encouraged and will promote additional opportunities for infiltration and evapotransporation (e.g., rain gardens, swales, etc.).
iv) Roof leaders discharging to the surface should extend at least 2 m from the building perimeter.

Physical Constraints & Limitations:

- Minimum infiltration rate of underlying native soils >15 mm/hr.
- In hilly areas, alterations to the natural topography should be minimized.

O&M Requirements:

- None.

1.1.2. Absorbent Landscaping/Soil Amendments

Absorbent landscaping consists of layer of suitable soil material overlain with vegetation. The primary objective of this BMP is to mimic the natural water balance by reducing runoff through increased infiltration and evapotranspiration, while also enhancing water quality through pollutant removal. To achieve these goals, runoff from impervious surfaces (e.g., rooftops, driveways, etc.) is directed to areas of absorbent landscaping, including lawns, planter boxes, rain gardens, etc.

Benefits:

- Reduces peak flows to receiving drainage infrastructure and/or watercourses.
- Enhances water quality through the removal of pollutants.
- Provides volume control and maintains water balance by promoting infiltration and evapotranspiration.

Design Considerations:

i) To meet the performance targets for this type of BMP, it is critical that the amount of absorbent landscaping is balanced with the corresponding impervious area (i.e., maximum 2:1 ratio).
ii) Conserve as much existing vegetation and native soils as possible, and minimize impervious areas.
iii) Absorbent landscaping areas should be graded to promote temporary ponding that infiltrates/ evapotranspirates.
iv) Ensure adequate growing medium (minimum 150 mm with 10% organic content for lawns and 450 mm with 15% organic content for shrub/tree areas).
v) Maximize vegetative cover with combination of native grasses, shrubs, and deciduous trees.

Physical Constraints & Limitations:

- Gradual slopes (i.e., less than 2%) with depressional areas to facilitate temporary storage of runoff.
- Maximum 2:1 ratio of impervious area to absorbent landscaping.
- Minimum infiltration rate of underlying native soils >15 mm/hr.
- Groundwater and bedrock levels >1 m below grade.

O&M Requirements:

- Weeding and replacing dead plants.
- Inspect overflow and remove debris.

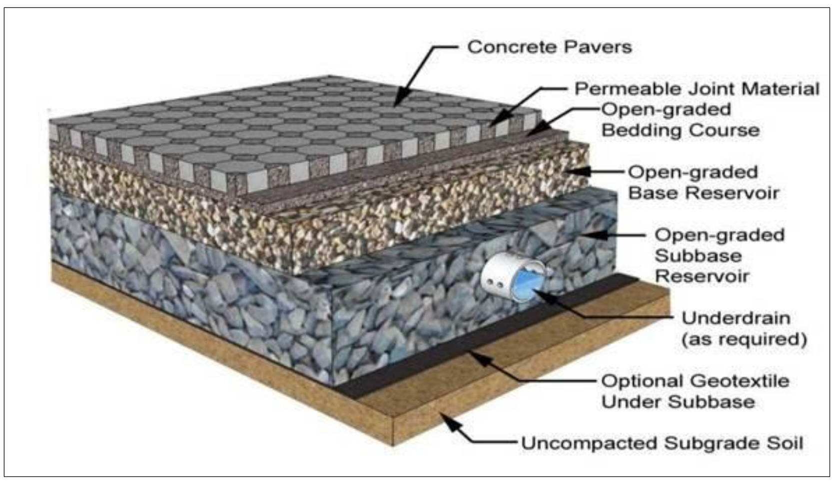
1.1.3. Permeable Pavement

As an alternative to traditional impervious pavement, permeable systems provide an opportunity for stormwater control where surface detention and treatment are limited due to physical constraints. Permeable pavement can be integrated with other BMPs as part of a 'treatment train' approach. There are many applications for permeable pavement systems, including driveways, sidewalk, roadway shoulders, parking lots/lanes, and pedestrian plazas. Furthermore, a wide range of permeable pavement types, which are listed below.

- Permeable interlocking concrete pavers;
- Plastic or concrete grid systems (i.e., grid pavers);
- Pervious concrete; and
- Porous asphalt.

As shown on the figure below, permeable pavement generally consists of the following components:

i) A permeable surface, which allows runoff to infiltrate into the ground;
ii) An underlying open-graded reservoir where the infiltrated precipitation is stored;
iii) A subgrade through which the infiltrated water is exfiltrated;
iv) A layer of non-woven geotextile; and
v) A perforated subdrain (where site constraints and/or native soil characteristics require).



***Source**: Interlocking Concrete Pavement Institute*

<u>Benefits:</u>

- Reduces peak flows to receiving drainage infrastructure and/or watercourses.
- Provides volume control and maintains water balance by promoting infiltration.

<u>Design Considerations:</u>

i) The type and configuration of permeable pavement should be selected based on site characteristics (i.e., climate, land use, topography, groundwater conditions) and anticipated vehicle loading.
ii) Permeable pavement systems should be installed on grades less than 2% to promote infiltration.

iii) To prevent groundwater contamination, permeable pavement systems should not receive runoff from high traffic areas where de-icing salts/sand are applied or potential contamination sources exist (e.g., gas stations, industrial sites, etc.). Alternatively, an impermeable liner and subdrain system should be incorporated into the design.
iv) Permeable pavement should not be used in areas subject to high traffic conditions or heavy vehicle loads.
v) In areas subject to high sediment levels, consideration should be given to incorporating vegetated filter strips and/or other BMPs up gradient of permeable paving systems to pre-treat runoff.

<u>Physical Constraints & Limitations:</u>

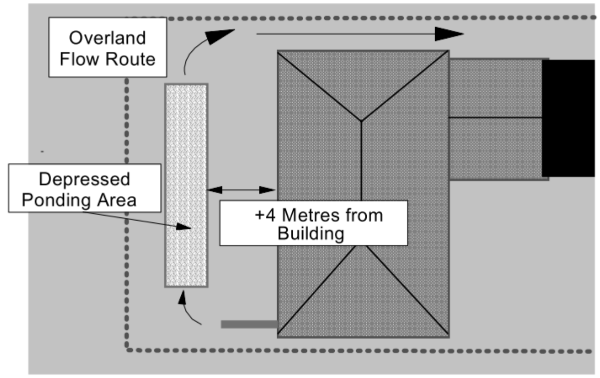
- Minimum infiltration rate of underlying native soils >15 mm/hr.
- Groundwater and bedrock levels >1 m below grade.
- Not suitable for high traffic conditions or vehicle loads.
- Groundwater separation (i.e., impermeable liner) is required for applications where water quality concerns exist, such as parking lots, industrial areas, etc.

<u>O&M Requirements:</u>

- None

1.1.4. Roof Downspout Disconnection

It has been demonstrated that directing roof leaders to permeable on-site areas can significantly reduce peak flows and runoff volumes contributing the receiving drainage system. This technique can be integrated with a variety of BMPs that will promote infiltration and/or evapotranspiration, including rain gardens, vegetated swales, and bio-infiltration systems in addition to rain barrels or cisterns for harvesting.



***Source**: MOE, 2013*

Benefits:

- Reduces peak flows to receiving drainage infrastructure and/or watercourses.
- Provides volume control and maintains water balance by promoting infiltration.

Design Considerations:

i) The type and configuration of permeable pavement should be selected based on site characteristics (i.e., climate, land use, topography, groundwater conditions) and anticipated vehicle loading.
ii) Permeable pavement systems should be installed on grades less than 2% to promote infiltration.
iii) To prevent groundwater contamination, permeable pavement systems should not receive runoff from high traffic areas where de-icing salts/sand are applied or potential contamination sources exist (e.g., gas stations, industrial sites, etc.). Alternatively, an impermeable liner and subdrain system should be incorporated into the design.
iv) Permeable pavement should not be used in areas subject to high traffic conditions or heavy vehicle loads.
v) In areas subject to high sediment levels, consideration should be given to incorporating vegetated filter strips and/or other BMPs up gradient of permeable paving systems to pre-treat runoff.

Physical Constraints & Limitations:

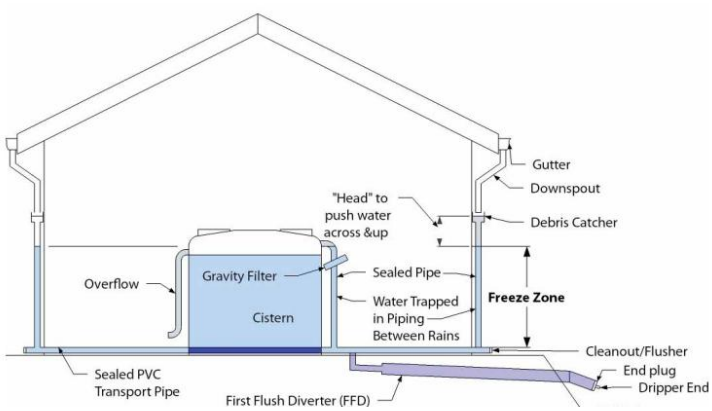
- Minimum infiltration rate of underlying native soils >15 mm/hr.
- Groundwater and bedrock levels >1 m below grade.
- Not suitable for high traffic conditions or vehicle loads.
- Groundwater separation (i.e., impermeable liner) is required for applications where water quality concerns exist, such as parking lots, industrial areas, etc.

O&M Requirements:

- None.

1.1.5. Rainwater Harvesting

Rainwater harvesting involves the capture and storage of runoff for subsequent re-use for irrigation needs, toilet flushing, or otherwise. Runoff from rooftops and other impervious surfaces is typically collected and conveyed to rain barrels, a cistern, or other storage system. When the collected rainwater is used to irrigate landscaped areas, it is infiltrated into the underlying soils or evapotranspirated by vegetation, which helps maintain the natural (pre-development) water balance.



Source: *Regional District of Nanaimo – Green Building Best Practices*

Benefits:

- Provides quantity control through attenuation of peak flows;
- Decreases the volume of runoff discharged to drainage infrastructure and receiving watercourses;
- Reduces demands on potable water sources for irrigation and other needs.

Design Considerations:

i) Pre-treatment is required through screening and/or first flush diverter to remove leaves, dirt, and other debris to prevent clogging within the conveyance and storage systems.
ii) The size of the storage system should be designed based on the contributing catchment area, together with anticipated rainwater re-use/irrigation needs and site constraints.
iii) The location of storage systems should be determined based on downspout location, site grading, and proximity to the irrigation area and overflow discharge location.
iv) Cisterns should be installed below the frost depth or indoors to prevent freezing during cold conditions.
v) Storage tanks must be equipped with overflow piping that is larger than the inlet piping.

Physical Constraints & Limitations:

- Stored rainwater must be used between rainfall events to provide capacity for the next storm.

O&M Requirements:

- The components of the rainwater harvesting system should be inspected periodically (i.e., gutters, downspouts, debris screens, storage tanks, overflow piping).
- Gutter cleaning
- Inspect overflow and remove debris
- Drain and disconnect piping prior to winter season in cold weather climates.