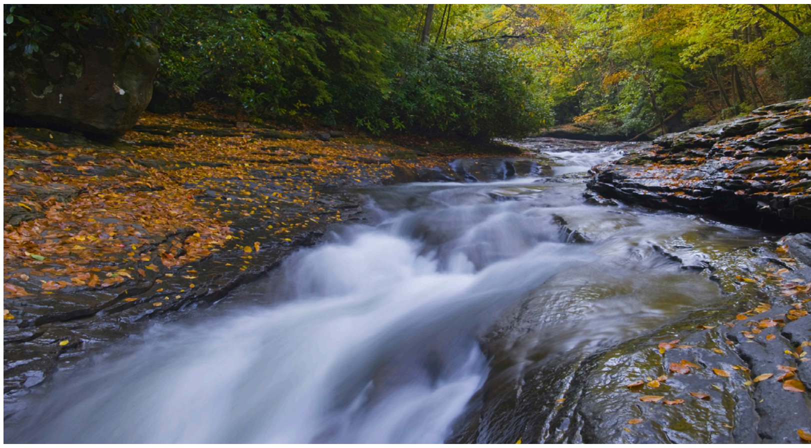

Stormwater Management Design Guidelines

Town of Wolfville
Prepared by Hatch Ltd. November 2019

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1. Scope

The municipal storm drainage system receives, conveys, and controls runoff in response to precipitation and snow melt. It consists of ditches, culverts, swales, subsurface interceptor drains, roadways, curbs and gutters, catchbasins, manholes, pipes, detention ponds and service lateral lines.

All storm drainage systems within the Town of Wolfville 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, onto downstream properties;
- to preserve designated natural watercourses and natural designated wetland environments;
- 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 Town of Wolfville, storm drainage systems are owned, operated, and maintained by either the Town of Wolfville Department of Public Works and Services, private landowners, or a combination of both.

The management and control of stormwater is a mixture of art and science, and like all other municipal services, storm drainage systems must be carefully designed, reviewed, and approved before construction proceeds. In addition to these design criteria, all storm drainage systems shall conform to any requirements established by the Nova Scotia Environment (NSE). No system shall be constructed until the design has been reviewed and approved by the Town of Wolfville Department of Public Works and Services (the Town) and by NSE, if applicable.

2. Engineering Responsibilities

The design of municipal storm drainage systems requires expertise in two basic fields:

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

Hydraulics, which is the determination of water flow characteristics in the channels, pipes, streams, ponds, and rivers which convey storm water.

The selection of the method(s) best suited for a design requires a qualified Professional Engineer (Consultant). Proposed storm drainage works must be based on sound engineering design with due consideration of potential environmental impacts. For stormwater design work, hydrologic and hydraulic modelling is required for the design of piped storm drainage systems, overland storm drainage systems, and stormwater detention facilities.

This document is intended to provide a guide for Stormwater Management Principles at the time of publishing. The field of stormwater management is always evolving and qualified professionals will apply the latest developments in approaches and technologies to meet the intent of this guide.

3. Design Approach

Design of storm drainage systems shall include consideration of both a minor storm drainage system and a major storm drainage system. The design of the dual storm drainage system, including the minor system and the major system, shall be carried out to ensure that no proposed or existing structure shall 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.

If the Consultant identifies an existing structure that may be damaged by the runoff generated by any storm up to the 1 in 100-year return period storm, the Consultant shall notify the Town so that the situation may be reviewed and resolved on an individual basis.

3.1. Major Storm Drainage System

The major storm drainage system shall be designed to convey stormwater runoff from 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 major storm event when the capacity of the minor storm drainage system is exceeded. The Consultant must ensure that the 1 in 100-year storm is safely conveyed from the site without causing downstream ponding or flooding anywhere in the Town. The major storm drainage system shall consist of the following components:

- ditches, open drainage channels, swales, roadways, detention ponds, watercourses, floodplains, canals, ravines, gullies, springs, and creeks in those areas where a piped storm drainage system is required for the minor drainage system;
- ditches, open drainage channels, swales, roadways, watercourses, floodplains, canals, ravines, gullies, springs, and creeks in those areas where an open channel drainage system is required for the minor drainage system .

3.2. Storm Drainage System Outfall

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

3.3. 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.

3.4. Basis of Design

Design of the dual storm drainage system shall be based on the full build out conditions based on the Land Use Bylaw.

3.5. Stormwater Management

Sound stormwater management requires skillful integration of the planning and design of piped stormwater systems, overland stormwater systems, and stormwater detention facilities recognizing and accounting for the effects of urbanization and climate change in terms of stormwater quantity and stormwater quality.

3.6. Stormwater Management Report

A stormwater management report shall be prepared and included as part of the submission for any development to examine the effect of the development on the receiving watercourses and downstream drainage systems.

The storm drainage report shall demonstrate how the design meets town requirements and include a Storm Servicing Schematic and Erosion and Sediment Control Plan.

3.7. Climate Change

Predicted impacts of climate change are constantly evolving with ongoing work by the scientific community. Within the body of literature on climate change, there is a high degree of variability in possible outcomes which are dependent on:

- The lifespan of the infrastructure in question;
- The climate model selected to predict climate impacts
- Variability in the model results, which tends to increase with longer time frames
- Assumptions on the amount of greenhouse gas mitigation undertaken on a global scale

Because there is such a high degree of variability in a developing area of practice, the Town intends to adopt a risk management approach to climate change adaptation. Infrastructure determined to be low risk based on the objectives in Section 1 may be assessed with less conservative assumptions about climate change impacts, while high risk infrastructure shall be assessed with more conservative assumptions about climate change impacts. The Stormwater Management Report shall provide justification for the selection of criteria to be used for climate change adaptation on the premise that the probability of future occurrence increases as the assumed magnitude of change decreases.

If determined necessary, the stormwater management report shall consider potential effects from sea level rise and increased precipitation intensity. Infrastructure can be categorized as high risk (e.g. dikes, pond embankments or areas with existing flooding concerns), medium risk (e.g. infrastructure adjacent to commercial or high traffic areas, highways, collector roads, areas adjacent to watercourses, or areas with downstream constrictions), or low risk (e.g. parks or upper elevation catchment areas).

The following resources may be used in developing a stormwater management strategy for the life cycle of drainage infrastructure, but are not intended to be an exhaustive or exclusive list:

Precipitation Changes

- Environment Canada, Climate Trends and Projections at www.canada.ca
- University of Western Ontario, IDF_CC tool for climate change modified IDF Curves
- Climate Data for Nova Scotia, www.climatechange.novascotia.ca

Sea Level Rise

- Intergovernmental Panel on Climate Change, latest Assessment Report (AR#)
- Estimating Sea Level Allowances for the Coasts of Canada and Adjacent United States Using the Fifth Assessment Report of the IPCC, Fisheries and Oceans Canada, 2014
- Geological Survey of Canada, Open File 7737, Relative Sea-level Projections in Canada and the Adjacent Mainland United States, James et. al., 2014
- Climate Data for Nova Scotia, www.climatechange.novascotia.ca

In this document, design storms refer to the referenced duration and return period with appropriate climate change factors applied to the data.

3.8. Net-Zero Increase Development

In recognition of the environmental impacts of urbanization, the effects of climate change, and the need to reduce the risk of property damage resulting from localized flooding, the Town of Wolfville has adopted a requirement for zero-net increase development in terms of stormwater management. The objective of this requirement is to ensure that the peak rate of stormwater discharge from a development does not exceed that of the pre-developed condition.

This requirement must be met for high-frequency, low-intensity storm events as well as low-frequency, high-intensity storm events. Confirmation of pre-development and post-development peak stormwater discharge rates will be assessed for the 2-hour and 24-hour duration storms with a 10- and 100-year return period.

3.8.1. *Pre-Development Condition*

For the pre-developed condition, hydrologic analysis shall be based on the land parcel in its natural condition at the time of application. The time of concentration (T_c) shall be based on natural flow patterns. Runoff hydrographs must be prepared for the 2, 5, 10, 25, 50 and 100-year design storm events for the pre-developed condition.

3.8.2. *Post-Developed Condition*

For the post-development condition, hydrologic analysis shall be based on the land parcel in its altered condition. The time of concentration (T_c) shall be based on the post-development flow patterns. Runoff hydrographs must be prepared for the 10 and 100-year design storm events for the post-development condition.

Adequate detention storage or other low impact development measures must be provided within the development to ensure that the post-development hydrographs, after routing through the detention storage, do not exceed the pre-development hydrographs.

3.9. Meteorological Data

Rainfall data is used in a variety of forms. Major and minor system capacity may be designed using the Rational Method. Storage for net-zero runoff control and low impact development measures shall be designed using an industry standard, hydrograph-based modelling methodology.

3.9.1. *Rainfall Intensity – Duration – Frequency Curve*

Intensity – Duration – Frequency (IDF) curves shall be based on data from the Kentville rain gauge published by the Atmospheric Environment Service (AES) of Environment Canada.

3.9.2. *Synthetic Design Storm*

Hydrograph methods to design 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 practice to use both synthetic and historical design storm hyetographs. Synthetic design storm hyetographs represent the statistical properties of recorded rainfall. Synthetic design storms shall be developed using SCS Type III, a symmetric Chicago Storm or Alternating Block, Method.

3.10. Runoff Methodology

There are numerous techniques and models available to determine stormwater runoff rates. 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. Appropriate techniques and models shall be selected and used by experienced professionals.

The following list of computational methods is not exclusive or exhaustive. This list provides general comments on several of the methods accepted by the Town. Alternate methods may be proposed with sufficient rationale.

3.10.1. The Rational Method

The Rational method is a 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 to determine instantaneous peak runoff in the design of storm drainage systems for up to 10 hectares in area, for preliminary design of systems serving larger areas, and as a check on flows determined by other methods. This method shall not be used to determine the size or hydraulic performance of storage facilities. The modified rational method shall not be used to size storage facilities.

3.10.2. 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.

3.10.3. SWMM

The United States Environmental Protection Agency (USEPA), Storm Water Management Model (SWMM) and other third-party developed interfaces for the SWMM model including Bentley CivilStorm, XP-SWMM and PC-SWMM for example, may be used for design of piped systems, modelling overland flow in a major system and modelling storage facilities.

Methods other than those listed above may be used if their use is justified by the Consultant and approved by the Town. Results may need to be verified by checking with a second method, or calibration based on flow measurement.

3.11. Hydrologic Design Parameters

3.11.1. Rational Method Runoff Coefficients

Table 1- Rational Method Runoff Coefficients

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
	Neighborhood	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	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
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

3.11.2. Time of Concentration and Lag Time

The 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. For runoff methods that use Lag Time (T_L) rather than Time of Concentration (T_c), the following accepted conversion shall be used:

Time of Concentration (T_c) = 1.7 x Lag Time (T_L)

For most piped systems in medium density urban areas, a minimum fifteen-minute inlet time (T_i) will be used. Travel times (T_t) in piped systems shall be based on velocities at peak design flow.

3.11.3. United States Soil Conservation Service Curve Numbers

Table 2 presents USSCS method curve numbers for various land uses and hydrologic conditions. Selection of values from Table 2 shall be based on impervious area, lot size, soil condition, and other relevant considerations. The curve numbers are intended for general guidance only, and the curve numbers of all development shall be calculated considering the values of pervious and impervious surfaces shown.

Table 2 - USSCS Method Curve Numbers

Character of Area	Hydrologic Condition	Average Impervious Area (%)	US SCS 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

3.11.4. Hydrologic Soil Group (HSG)

The USSCS categorizes soils into one of four hydrologic soil groups (HSG) contingent upon its surface infiltration rate, and subsurface permeability rate. Table 3 presents USSCS hydrologic soil groups. In lieu of detailed soil analysis, the Consultant may select USSCS curve numbers assuming hydrologic soil group "D". Soil analysis can also be selected based on test pits in the study area and the soil groups shown in Table 3.

Table 3 - USSCS Hydrologic Soil Group (HSG) Classification

USSCS Hydrologic Soil Group	Description	Soil Type	Permeability Class	Hydraulic Conductivity Range (m/sec)x10^-6	Hydraulic Conductivity Average (m/sec)x10^-6
A	Very low runoff potential Very high infiltration rate (consistent with well drained sand and gravel)	*rock, clean gravel *medium to coarse sand	*High *Acceptable	>500 20 - 500	N/a 260
B	Moderate runoff potential Moderate infiltration rate (consistent with silt and sand)	*fine sandy gravel	*Acceptable	20 - 80	50
C	High runoff potential Low infiltration rate (consistent with clay and silt)	*sandy silt	*Acceptable	3 - 8	5
D	Very high runoff potential Very low infiltration rate (consistent with saturated clays and high water tables)	*clayey silt *clay	*Low *Low	0.8 - 3 <0.8	1.5 N/a

4. Design Requirements

Major storm drainage systems shall be designed to convey, without overtopping, the 1 in 100-year storm.

The capacity of a proposed or existing storm conveyance system shall be checked using Manning's Equation, accounting for head loss through the conveyance system as well as any junctions such as manholes and bends provided there is no surcharge. A more detailed model of the system to determine the hydraulic gradeline (HGL) shall be required if system surcharging is unavoidable during the design event. The model shall take into account losses at manholes and other junctions, the headloss through the pipes, and any backwater conditions at the outlet of the storm system.

It is possible that during a major storm, flows greater than that of a 1 in 10-year return period storm will enter the storm sewer system, and the Consultant may need to limit the quantity of stormwater runoff that enters the minor storm drainage system.

4.1. Minimum Velocity

Under peak design flow (PDF) conditions from the tributary area, when fully developed, stormwater flow velocities shall be a minimum of 0.6 m/s.

4.2. Maximum Velocity

Under peak design flow (PDF) conditions from the tributary area, when fully developed, stormwater flow velocities shall be a maximum of 4.5 m/s. If this velocity is exceeded, the consultant shall demonstrate how the infrastructure will be protected from abrasion, hydraulic jumps or surcharged conditions at junctions.

4.3. Minimum Diameter

Storm sewer main diameters shall not be less than 300 mm. Catchbasin lead diameters shall not be less than 200 mm.

4.4. Changes in Diameter

Storm sewer main diameter must not decrease in the downstream direction. Manholes are to be provided where the storm sewer main diameter changes or where pipes require horizontal or vertical deflection.

4.5. Minimum Slope

The minimum pipe slope for storm sewer mains is 0.4%. **Under special conditions, if full and justifiable reasons are given, slopes less than 0.4% may be permitted provided that self-cleansing velocities under full flow conditions are maintained.**

4.6. Minimum Depth

The depth of storm sewer mains measured from the design grade of the finished surface to the top of the pipe must be a minimum of 1.2 m. However, the Consultant shall ensure that the storm sewer is deep enough not to cause flooding to buildings during the 1 in 100 year design storm.

4.7. Location

Wherever possible, all storm sewer mains and appurtenances shall be located within the street right-of-way or a MSE in favour of the Town. All storm drainage outfalls shall be located within a Municipal Service Easement (MSE) in favour of the Town.

Municipal Service Easements shall be of sufficient width to allow safe excavation of the storm sewer in accordance with the requirements of Worker's Compensation Board of Nova Scotia. Depending upon the length and location of the Municipal Service Easement (MSE), the Town may require a travel way to be provided within the Municipal Service Easement for access and maintenance purposes.

Where Master Planning indicates a need to accommodate future upstream lands naturally tributary to the drainage area, a Municipal Service Easement (MSE) shall be provided from the edge of the street right-of-way to the upstream limit of the subdivision.

The minimum width of a municipal service easement shall be 6.0 m. However, the actual width shall depend upon the depth and size of any storm appurtenance contained therein such that safe excavation is possible.

4.8. Manholes

A manhole must be provided on a storm sewer main at any change in diameter, material, horizontal alignment, vertical alignments, pipe main intersections or at the end of a pipe, Manhole spacing shall not exceed 120 m.

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 a different drop is determined by appropriate calculations;
- At each junction, the following additional invert drops shall be provided to account for junction head loss:
  - straight through: 25mm
  - up to 45 degree deflection: 50mm
  - up to 90 degree deflection: 75mm
- Pipe deflections greater than 90 degrees shall not be permitted
- 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. Manhole ladders are not required.

4.9. Service Laterals

All 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 by the Town;
- Service laterals shall be a minimum of 150mm in diameter, and shall be sized by the Consultant for commercial, industrial or multi-family lots, or where roof drainage is to be directly connected to the lateral.
- For semi-detached lots, two storm drainage service laterals are required;
- The storm drainage lateral shall be laid at a minimum grade of 1.0% to the limit of the street right-of-way;
- The depth of storm drainage laterals shall be of sufficient depth to connect foundation drains for full depth residential basements. In areas where this requirement cannot be met, the Subdivision Grading and Drainage Plan must reflect half-depth residential basements, or slab-on-grade foundations.

4.10. 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 resulting from groundwater migration shall be employed.

4.11. 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 elevation of the lateral at the property line shall be established at least 0.5m above the elevation of the crown of the storm sewer main at the point of connection.

Where a minor storm drainage system does not exist, other options are permitted as specified in the National Building Code. In using other alternatives, Subdivision 9.14 of the National Building Code shall be applicable.

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

4.12. Roof Drains

Residential 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.

Commercial/Industrial roof drains may be connected to the internal private stormwater arrangement provided that the rainwater flows are incorporated into the pre-development and post-development flows for the site.

4.13. Catchbasins

Catchbasins shall be installed flush with the back of the gutter. The maximum area draining to any catchbasin is 500 m2 for grades up to 3.5%, 350 m2 for steeper grades and 1000 m2 for catchbasins installed off-street.

Catchbasins at sag points in roads or off-street lots shall be assessed for the depth of ponding during the 100-year return period storm. Inlet capacity can be assessed using the orifice equation:

$$Q = 0.67\ C\ A\ (2\ g\ h)^{0.5}$$

Q	capacity (m^3/s)
0.67	clogging factor
C	discharge coefficient (0.8)
A	open area (m^2)
g	gravitational acceleration (9.81 m/s^2)
h	depth of ponding (m)

1 in 100-year ponding depth shall be less than 120 millimeters and shall not cause runoff to be directed onto private property or risk flooding adjacent lots.

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 completely 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 10-year return period storm, the actual flows captured by the catchbasins during the 1 in 100 year return period storm shall not be permitted to surcharge the main and flood storm laterals during major storm events.

5. Low Impact Development

Low impact development (LID) is a stormwater management strategy that seeks to mitigate the impacts of increased runoff and stormwater pollution by managing runoff as close to its source as possible. LID comprises a set of site design strategies that minimize runoff and distributed, small scale structural practices that mimic natural or predevelopment hydrology through the processes of infiltration, evapotranspiration, harvesting, filtration and detention of stormwater. These practices can effectively remove nutrients, pathogens and metals from runoff, and they reduce the volume and intensity of stormwater flows.

This section outlines the Water Quality requirement and provides an overview of different LID stormwater management practices including a description, general design guidelines, and operation and maintenance recommendations for each.

5.1. Water Quality Requirement

The objectives of the Water Quality requirement are as follows:

- Reduce pollution in runoff and protect nearby waters from adverse impacts of runoff;
- Recharge the groundwater level; and
- Restore more natural site hydrology

The Water Quality requirement focuses on the removal of pollutants from stormwater runoff. Water quality benefits are provided by slowing water down and allowing suspended solids to settle. This basic treatment mechanism can have multiple benefits because some nutrients, metals, organics, and other contaminants are bound to these sediment particles. Generally, the physical, chemical, and biological processes that take place in a system incorporating soil, water, and plants provide the best water quality improvements.

Infiltration provides groundwater recharge needed to restore more natural site hydrology. Loss of annual recharge to groundwater can be minimized using infiltration measures including environmentally sensitive site design, low impact development techniques, stormwater best management practices, and good operation and maintenance. Infiltration is defined as the passage or movement of water into the soil surface. Infiltration of stormwater runoff can significantly reduce pollutant loads reaching surface water and generally does not pose a threat to groundwater quality if there is enough separation from the water table. Infiltration is a major focus of the Water Quality requirement.

The Water Quality requirement stipulates capture, treatment, and infiltration of the first 25 mm of rainfall times the total impervious area at a development site. See equation below. This volume of runoff is referred to as the water quality or recharge volume. Impervious area is any surface that significantly limits stormwater infiltration such as asphalt, concrete or clay..

$$WQV = \left(\frac{P}{1000}\right) x \ (Area_{imp})$$

Where: *WQV* = Water Quality Volume (m^3)
P = 25 mm
$Area_{imp}$ = Impervious Area within the development site (m^2)

Proponents shall size the infiltration stormwater management practices so that they infiltrate the required water quality volume. Design sizing calculations must assume that no infiltration occurs until the infiltration system is filled to the elevation associated with the required water quality volume.

If infiltration is infeasible, or where it can be demonstrated that infiltration would cause property or environmental damage, the water quality volume not infiltrated must be routed through an acceptable pollutant-reducing practice and for no more than 72 hours. If the applicant believes that infiltration is not feasible, a waiver from the infiltration requirement must be submitted to the Town for approval.

5.2. Storm Water Management Practices

Recommended LID stormwater management practices for achieving the Water Quality requirement are listed below.

5.2.1. Enhanced Grass Swales

Description

Enhanced grass swales also known as enhanced vegetated swales are vegetated open channels designed to convey, treat and attenuate stormwater runoff. Check dams and vegetation in the swale slows the water flow to allow sedimentation, filtration through the root zone and soil matrix, evapotranspiration, and infiltration into the underlying native soil. Enhanced grass swales incorporate design features such as modified geometry and check dams that improve the contaminant removal and runoff reduction functions of simple grass channel and roadside ditch designs.[1]

Source: Chesapeake Stormwater Network

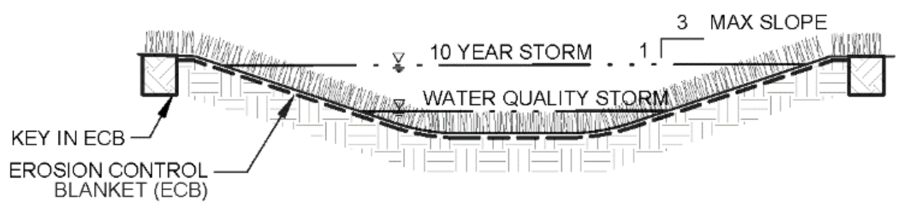
Source: Limnotech

Design Guidelines

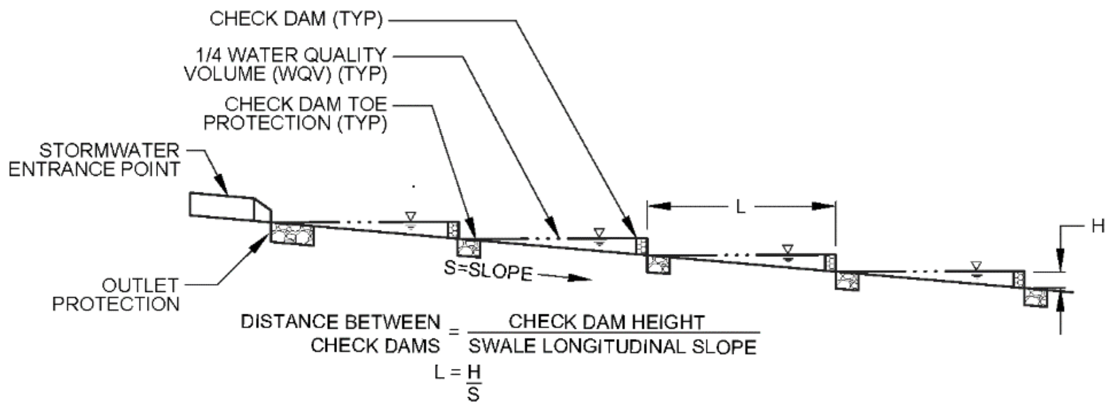
- *Design Criteria*: Grass swales shall be designed to store and infiltrate water quality volume. The design storm event is a 4-hour, 25 mm design storm event. The entire contributing area shall be included for the flow calculations.
- *Erosion*: Incorporating check dams can prevent erosion. Additionally, designers can use permanent reinforcement matting on swales designed for high velocity flows and temporary matting during the vegetation establishment period.[1]
- *Ponding*: Grass swales shall be designed to allow ponding of stormwater for no longer than 24 hours following a storm event.
- *Shape:* Grass swales shall be designed with a trapezoidal or parabolic cross section.

- *Bottom Width*: Grass swales shall be designed with a bottom width between 0.75 m and 3.0 m. The design width shall allow for shallow flows and adequate water quality treatment, while preventing flows from concentrating and creating gullies.
- *Slopes*: Longitudinal slopes between 0.5% and 6% are allowable. On slopes steeper than 3%, check dams shall be used.
- *Side Slopes*: Side slopes 3:1 (H:V) or milder are required.
- *Check Dams*: Check dams may be constructed of stone layers or timber and stone. The maximum height of check dam shall be 300 mm.
- *Flow Depth*: The maximum flow depth shall correspond to two-thirds the height of the vegetation. Vegetation in some grass swales may reach heights of 150 mm; therefore, a maximum flow depth of 100 mm is recommended during a design storm event.
- *Design velocity and capacity*: Design stormwater conveyance using Manning's Formula. Grass swales must be designed for a maximum velocity of 0.6 m/s or less for the design storm event. The swale shall also convey the 10-year storm at non-erosive velocities with a minimum of 150 mm of freeboard. Swales shall overflow and discharge to a major storm drainage system designed to meet the requirements within this manual.
- *Water Table*: Provide a 600 mm buffer between the swale bottom and seasonal high groundwater elevation or bedrock.
- *Setback from Buildings:* Enhanced grass swales shall be setback four (4) meters from building foundations.
- *Infiltration*: Native soils shall have infiltration rates of 15 mm/hr or greater. Soils with less than 15 mm/hr infiltration rate shall be tilled to a depth of 300 mm and amended with compost to achieve an organic content of between 8 and 15% by weight or 30 to 40% by volume prior to planting.
- *Pretreatment*: Pretreatment with vegetated filter strip or pea gravel diaphragms is recommended. The pea gravel diaphragm shall be washed stone between 3 and 10 mm in diameter and a minimum of 300 mm wide and 600 mm deep. Sediment forebays are acceptable option for concentrated inflows from larger contributing areas.

- *Landscaping*: Designers shall choose grasses that can withstand both wet and dry periods as well as relatively high velocity flows within the swale. For applications along roads and parking lots, where snow will be plowed and stored, non woody and salt tolerant species shall be chosen.[1]
- *Drainage Area and Runoff Volumes:* The swale geometry, storage volume and conveyance capacity depends on the size of contributing drainage area. Typical ratios of impervious drainage area to swale area range from 5:1 to 10:1. The contributing drainage area is generally limited to 2 hectares.[1]



Typical Section



Typical Profile

Operations & Maintenance

Table 5 Enhanced Grass Swale

Task	Description	Frequency
Remove trash and debris	Remove trash and debris from pretreatment devices, the swale surface and inlet and outlets	At least 2 times a year
Remove sediment	Remove sediment from pretreatment devices, the swale surface and inlet and outlets	Annually
Mow	Mow grass to maintain height between 75 mm and 150 mm	Once a month during growing season.
Repair areas of erosion	Repair areas of erosion and revegetate	As needed, but no less than once a year.

5.2.2. Dry Swale

Description

A dry swale is also referred to as a bio-swale or infiltration swale. A dry swale is a design variation of the enhanced grass swale that incorporates an engineered soil media or clean topsoil bed, gravel storage layer, and an optional perforated pipe underdrain system.[1] A dry swale can also be thought of as a bioretention cell configured as an open channel. A dry swale provides additional water balance and water quality benefits due to the engineered soil media or clean topsoil and storage capacity when compared to the enhanced grass swale. A dry swale can be vegetated with grass or more elaborate planting.

Source: Sustainable Technologies

Design Guidelines

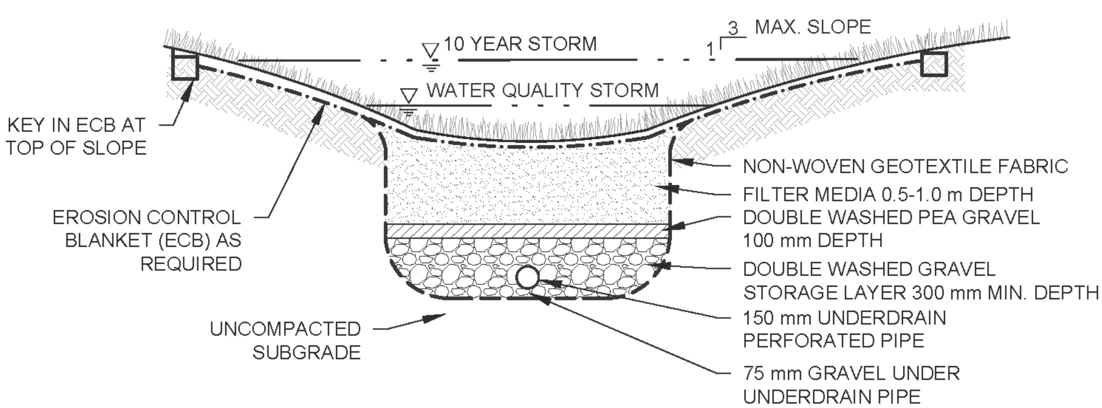
- *Design Criteria*: Dry swales shall be designed to store and infiltrate water quality volume. The design storm event is a 4-hour, 25 mm design storm event. The entire contributing area shall be included for the flow calculations.

- *Erosion*: Incorporating check dams can prevent erosion. Additionally, designers can use permanent reinforcement matting on swales designed for high velocity flows and temporary matting during the vegetation establishment period.[1]
- *Ponding*: Dry swales shall be designed to allow ponding of stormwater for 24 to 72 hours following a storm event.
- *Shape:* Grass swales shall be designed with a parabolic cross section; however, a trapezoidal cross section may be designed as long as the engineered soil or clean topsoil bed boundaries lay in the flat bottom areas.
- *Bottom Width*: For the trapezoidal cross section, the bottom width shall be between 0.75 m and 3.0 m. The design width shall allow for shallow flows and adequate water quality treatment, while preventing flows from concentrating and creating gullies.
- *Slopes*: Longitudinal slopes between 0.5% and 6% are allowable. On slopes steeper than 3%, check dams are be used.
- *Side Slopes*: Side slopes 3:1 (H:V) or milder are required.
- *Check Dams*: Check dams may be constructed of stone layers or timber and stone. The maximum height of check dam shall be 300 mm.
- *Flow Depth*: The maximum flow depth shall correspond to two-thirds the height of the vegetation. Vegetation in some grass swales may reach heights of 150 mm; therefore, a maximum flow depth of 100 mm is recommended during a design storm event.
- *Design velocity and capacity*: Design stormwater conveyance using Manning's Formula. Dry swales must be designed for a maximum velocity of 0.6 m/s or less for the design storm event. The swale shall also convey the 10-year storm at non-erosive velocities with a minimum of 150 mm of freeboard. Swales shall overflow and discharge to a major storm drainage system designed to meet the requirements within this manual.
- *Water Table*: Provide a 600 mm buffer between the swale bottom and seasonal high groundwater elevation or bedrock.
- *Setback from Buildings:* Dry swales shall be setback four (4) meters from building foundations. When located within three (3) meters of building foundations, an impermeable liner and perforated pipe underdrain system shall be used.[1]

- *Infiltration*: Native soils shall have infiltration rates of 15 mm/hr or greater. An underdrain is required for soils with less than 15 mm/hr infiltration rate.
- *Pretreatment*: Pretreatment is required. Options include a vegetated filter strip a minimum of 3 m, a sediment forebay with a volume accounting for 25% of the water quality storage requirement and be designed with a 2:1 length to width ratio, or a pea gravel diaphragm. Rip-rap and/or dense vegetation is acceptable as pretreatment on small swales with a drainage area less than 100 square meters.
- *Gravel Storage Layer:* Shall be a minimum of 300 mm deep and sized to provide the required storage volume. Granular material shall be open-graded, clean, double-washed crushed rock, 25 mm max., 5 mm min. with minimum 40% void space. Pea gravel choking layer: A 100 mm deep layer of clean, double-washed pea gravel (9.5 mm to 2.4 mm) shall be placed on top of the coarse gravel storage layer as a choking layer separating it from the overlying filter media bed.
- *Underdrain*: Minimum of 150 mm diameter perforated pipe installed 75 mm above the bottom of the gravel storage layer. HDPE with smooth interior walls or PVC material. Underdrains shall be capped on the upstream end(s) and connected to the storm conveyance system.
- *Monitoring Wells*: A capped vertical standpipe consisting of an anchored 150-mm diameter perforated pipe with a lockable cap installed to the bottom of the facility at the downgradient end for monitoring the length of time required to fully drain the facility between storms. Connect to underdrains.
- *Filter Media:* The recommended minimum filter bed depth is 1.0 meter with trees. Total volume 30 m^3/tree or 20 m^3/tree for trees sharing soil. Pollutant removal benefits may be achieved in filter beds as shallow as 500 millimeters for designs using perennials, shrubs, or grasses. Filter media shall come pre-mixed from a vendor. The filter media soil mixture composition:
    1) Sand 75-85%
    2) Fines 2-5%
    3) Organic Matter 8-10%
    4) P-index value 12-30 ppm
    5) Soluble Salts < 2.0mmhos/cm
    6) Cationic exchange capacity > 5 meq/100 g

7) pH 5.5-7.5
8) Infiltration rate>120 mm/hr, max 300 mm/hr
9) The mixture shall be free of stones, stumps, roots, or other similar objects larger than 50 mm.

- *Geotextile:* Nonwoven needle punched fabric with a recommended typical weight of 203 g/m².
- *Mulch:* A 75-millimeter layer of shredded hardwood bark mulch or a temporary or permanent erosion control matting on the surface of the filter bed is recommended. The matting shall be coconut fiber and shall be installed prior to the landscaping.
- *Landscaping*: Designers shall choose grasses, herbaceous plants, or trees that can withstand both wet and dry periods as well as relatively high velocity flows within the swale. For applications along roads and parking lots, where snow will be plowed and stored, non woody and salt tolerant species shall be chosen.[1]
- *Drainage Area and Runoff Volume*: Dry swales typically treat drainage areas of less than two (2) hectares. If dry swales are used to treat larger areas, the velocity through the swale becomes too great to treat runoff or prevent erosion. Typical ratios of impervious drainage area to dry swale area range from 5:1 (commercial or industrial application) to 15:1 (residential application).[1]
- *Sizing*: The sizing methodology for the dry swale is the same as that for bioretention cells. See section 5.2.4.



Typical Section

Operations & Maintenance

More intensive maintenance is required in the first 6 months. The swale shall be inspected after each storm greater than 10 mm, or a minimum of twice. Two or three growing seasons may be required to establish vegetation. As plants are becoming established, activities such as watering, weed removal, and replacement of dead plants will be required. Typical maintenance after the establishment period is outlined below.

Table 6 Dry Swale Maintenance Recommendations

Task	Description	Frequency
Remove trash and debris	Remove trash and debris from pretreatment devices, the swale surface and inlet and outlets.	At least 2 times a year
Remove sediment	Remove sediment from pretreatment devices, the swale surface and inlet and outlets.	Annually
Mow	Mow grass to maintain height between 75 to 150 mm.	Once a month during growing season.
Repair areas of erosion or channelization	Repair areas of erosion and revegetate. If gullies are observed along the swale, regrading and revegetating may be required.	As needed, but no less than once a year.
Remulch, weed, and prune	Prune trees and shrubs. Replace dead vegetation, remove invasive growth, and dethatch.	As needed, but no less than once a year.

5.2.3. Rain Garden

Description

A rain garden is a landscaped, shallow depression that is designed to intercept, treat, and infiltrate stormwater at the source before it becomes runoff. The plants used in the rain garden are native to the region and help retain pollutants that could otherwise harm nearby waterways. Rain gardens, though similar to bioretention cells, are smaller scale systems, frequently used on residential lots with simple overland outlets or overflows, and soil amendments for planting beds.

Source: Maplewood, MN

Design Guidelines

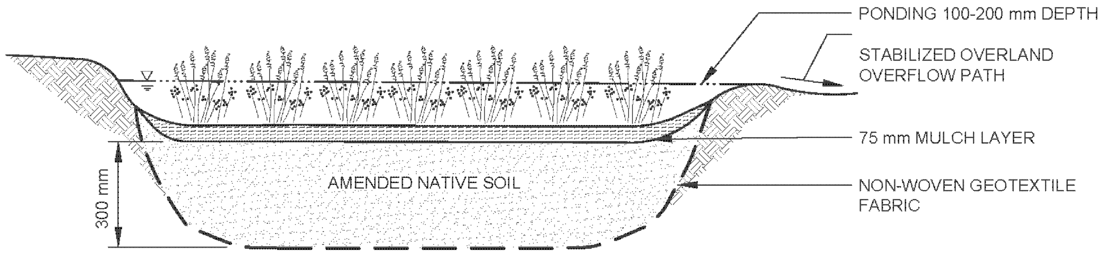
- *Design Criteria*: Rain gardens shall be designed to store and infiltrate or detain and slowly release water quality volume.
- *Water Table*: Provide a 600 mm buffer between the swale bottom and seasonal high groundwater elevation or bedrock.
- *Building Setback*: The rain garden shall be setback at least three (3) meters from building foundations so infiltration water doesn't seep into the foundation.
- *Placement*: Place in full or partial sunlight. Do not place them near septic systems or in places where water already ponds. Select a flat or gently sloping area.
- *Ponding Depth*: Between 100 and 200 mm.
- *Water Table*: Provide a 600 mm buffer between the facility bottom and seasonal high groundwater elevation or bedrock.
- *Infiltration*: Native soils shall have infiltration rates of 15 mm/hr or greater. An underdrain is required for soils with less than 15 mm/hr infiltration rate.

- *Drainage Area and Runoff Volume:* The size of the rain garden is a function of volume of runoff to be treated and recharged and is sized to handle the water quality design storm based on the drainage area. Impervious contributing area to treatment facility area ratio shall be 5:1 to 15:1. A typical residential rain garden ranges from 10 m^2 to 30 m^2. Size of contributing drainage area shall be less than 1000 m^2.
- *Pretreatment:* Pretreatment is recommended. Options include a sediment forebay, vegetated filter strip a minimum of 3 meters in width, pea gravel diaphragm, enhance grass swales, and leaf screens on roof down spouts.

Source: Deer Creek Watershed Alliance

- *Soils:* The recommended depth of 300 mm amended soil. Organic content shall be 8-15% by weight or 30-40% by volume.
- *Geotextile*: Nonwoven needle punched fabric with a recommended typical weight of 203 g/m^2.
- *Mulc*h: A 75-millimeter layer of shredded hardwood bark mulch is recommended.
- *Overflows*: Designs shall ensure that facility overflows drain to the municipal minor/major drainage system or natural drainage path, and do not discharge to or through adjacent sites. Overflow device shall be sized to safely convey larger storm events (2-year to 100-year).
- *Surface:* Ensure that the surface of the rain garden is level.
- *Drain Down:* Rain gardens shall be designed to allow ponding of stormwater for 24-hours to 36-hours following a storm event.

- *Landscaping:* Designers shall choose a combination of native trees, shrubs, and perennial herbaceous plants. "Wet footed" plants, such as wetland forbs, shall be planted near the center, whereas upland species are better for the edges of the rain gardens. For applications along roads and parking lots, where snow will be plowed and stored, non woody and salt tolerant species shall be chosen.[1]



Typical Section

Operations & Maintenance

Table 7 Rain Garden Maintenance Recommendations

Task	Description	Frequency
Repair erosion	Repair planting soil bed if erosion occurs	As needed
Core aerate of cultivate unvegetated areas	Core aerate of cultivate unvegetated areas if surface becomes clogged with fine sediments.	Annually
Apply mulch	Apply mulch over surface	2 times per year
Weed and replace plants	Replace dead vegetation and remove invasive growth	As needed at least 2 times per year
Inspect and remove sediment and debris	Remove sediment, debris, and leaves at inflow and outflow devices	Monthly

5.2.4. *Bioretention Cells*

Description

As a stormwater filter and infiltration practice, bioretention temporarily stores, treats and infiltrates runoff. Depending on native soil infiltration rate and physical constraints, the system may be designed without an underdrain for full infiltration, with an underdrain for partial infiltration, or with an impermeable liner and underdrain for filtration only. The primary component of a bioretention practice is the filter bed which is a mixture of sand, fines and organic material. Other elements of bioretention include a mulch ground cover and plants adapted to the conditions of a stormwater practice. Pretreatment, such as a settling forebay, vegetated filter strip, or stone diaphragm, often precedes the bioretention to remove particles that would otherwise clog the filter bed. Bioretention is designed to capture the water quality storage requirement. An overflow or bypass is necessary to pass large storm event flows.[1]

Source: Hatch

Design Guidelines

- *Design Criteria:* Bioretention shall be designed to store and infiltrate or detain and slowly release water quality volume.
- *Site Topography*: Bioretention is best applied in a location where slopes are between 1 to 5%. A stepped multi-cell design can be used when a flat surface cannot be maintained along the length of a linear bioretention.[1]

- *Water Table*: Provide a 600 mm buffer between the swale bottom and seasonal high groundwater elevation or bedrock.
- *Building Setback:* Bioretention cells shall be setback four (4) meters from building foundations. When located within four (4) meters of building foundations, an impermeable liner and perforated pipe underdrain system shall be used.[1]
- *Infiltration*: Native soils shall have infiltration rates of 15 mm/hr or greater. An underdrain is required for soils with less than 15 mm/hr infiltration rate.
- *Drainage Area and Runoff Volume:* The size of the bioretention cell is a function of volume of runoff to be treated and recharged and is sized to handle the water quality design storm based on the drainage area. A typical drainage area is between 1000 m^2 to 0.5 hectare. The maximum recommended drainage area to one bioretention facility is 0.8 hectares. Impervious contributing area to treatment facility area ratio shall be between 50:1 for residential developments and 20:1 for industrial or commercial developments, or parking lots.[2]
- *Pretreatment:* Pretreatment is required. Pretreatment prevents premature clogging of bioretention facilities by capturing coarse sediment particles before they reach the filter bed. Options include a sediment forebay, vegetated filter strip a minimum of 3 meters in width, pea gravel diaphragm, enhance grass swales, and mechanical pretreatment devices.
- *Inflow:* Stormwater runoff inflow may be directed to the bioretention cell from downspouts to a forebay or stone energy dissipater; sheet flow off of a depressed curb; one or more curb cuts; covered drains that convey flows across sidewalks from the curb or downspouts; grates or trench drains that capture runoff from the sidewalk or plaza.
- *Gravel Storage Layer:* Shall be a minimum of 300 mm deep and sized to provide the required storage volume. Granular material shall be open-graded, clean, double-washed crushed rock, 25 mm max., 5 mm min. with minimum 40% void space. Pea gravel choking layer: A 100 mm deep layer of clean, double-washed pea gravel (9.5 mm to 2.4 mm) shall be placed on top of the coarse gravel storage layer as a choking layer separating it from the overlying filter media bed.

- *Underdrain*: Minimum of 150 mm diameter perforated pipe installed 75 mm above the bottom of the gravel storage layer. HDPE with smooth interior walls or PVC material. Capped at upstream end.

Source: Hatch

- *Monitoring Wells*: A capped vertical standpipe consisting of an anchored 150-mm diameter perforated pipe with a lockable cap installed to the bottom of the facility for monitoring the length of time required to fully drain the facility between storms. Connect to underdrains.

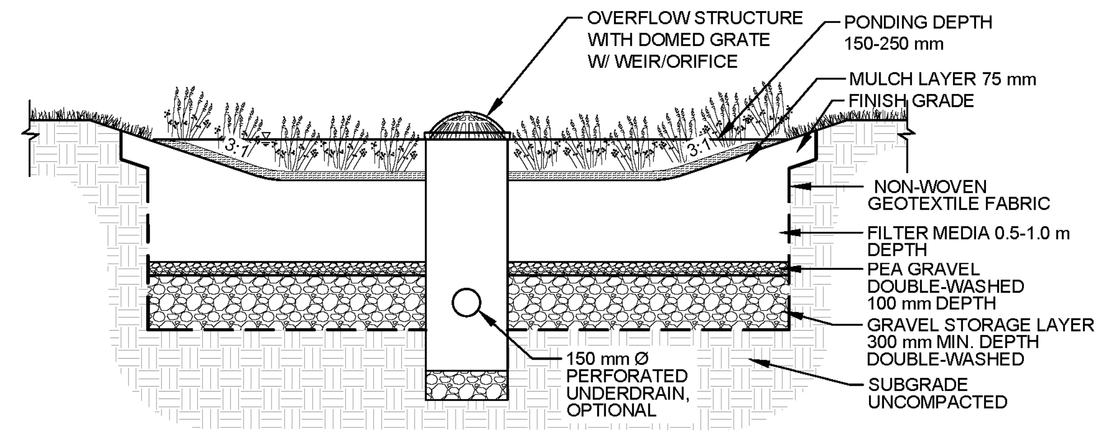
- *Filter Media:* The recommended minimum filter bed depth is 1.0 meter with trees. Total volume 30 m^3/tree or 20 m^3/tree for trees sharing soil. Pollutant removal benefits may be achieved in filter beds as shallow as 500 mm for designs using perennials, shrubs, or grasses. Filter media shall come pre-mixed from a vendor. The filter media soil mixture composition:

    1) Sand 75-85%
    2) Fines 2-5%
    3) Organic Matter 8-10%
    4) P-index value 12-30 ppm
    5) Soluble Salts < 2.0mmhos/cm
    6) Cationic exchange capacity > 5 meq/100 g
    7) pH 5.5-7.5
    8) Infiltration rate>120 mm/hr, max 300 mm/hr
    9) The mixture shall be free of stones, stumps, roots, or other similar objects larger than 50 mm.

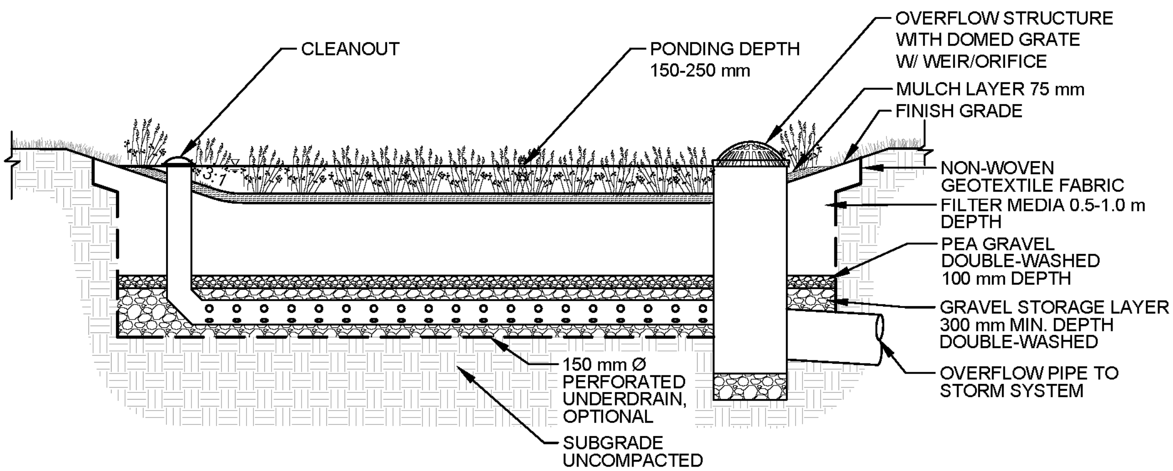
Source: Hatch

- *Geotextile*: Nonwoven needle punched fabric with a recommended typical weight of 203 g/m^2.

- *Mulc*h: A 75-millimeter layer of shredded hardwood bark mulch or a temporary or permanent erosion control matting on the surface of the filter bed is recommended. The matting shall be coconut fiber and shall be installed prior to the landscaping.
- *Overflows*: Designs shall ensure that facility overflows drain to the municipal minor/major drainage system or natural drainage path, and do not discharge to or through adjacent sites. Overflow device shall be sized to safely convey larger storm events (2-year to 100-year). Overflow elevation shall be set at a maximum of 250 mm above filter bed surface. If a riser structure is used it shall have a metal beehive grate.
- *Ponding:* Maximum ponding depth is between 150-250 mm. Ensure that the surface of the bioretention facility is level.
- *Drain Down:* Bioretention cells shall be designed to allow ponding of stormwater for 48 hours (recommended) and a maximum of 72 hours following a storm event.
- *Landscaping:* Designers shall choose a combination of native trees, shrubs, and perennial herbaceous plants. “Wet footed” plants, such as wetland forbs, shall be planted near the center, whereas upland species are better for the edges of the bioretention area. For applications along roads and parking lots, where snow will be plowed and stored, non woody and salt tolerant species shall be chosen.[1]



Typical Section



Typical Longitudinal Section

Operations & Maintenance

More intensive maintenance is required in the first 6 months. The bioretention shall be inspected after each storm greater than 25 mm, or a minimum of four times a year. Two or three growing seasons may be required to establish vegetation. As plants are becoming established, activities such as watering, weed removal, and replacement of dead plants will be required. Typical maintenance after the establishment period is outlined below.

Table 8 Bioretention Cells Maintenance Recommendations

Task	Description	Frequency
Inspect and remove sediment and debris	Remove sediment from pretreatment areas, the surface, and inlet/outlets.	Quarterly
Repair areas of erosion	Repair areas of erosion and revegetate. If gullies are observed on the surface, regrading and revegetating may be required.	Annually
Remulch, weed, and prune	Prune trees and shrubs. Replace dead vegetation, remove invasive growth, and dethatch. Apply mulch over surface	As needed, but no less than 2 times a year.
Vacuum clean structures and jet-rod pipes	Remove trash, sediment, and debris from subsurface access and flow control structures. Jet-rod conveyance, distribution, and underdrain pipes	Annually

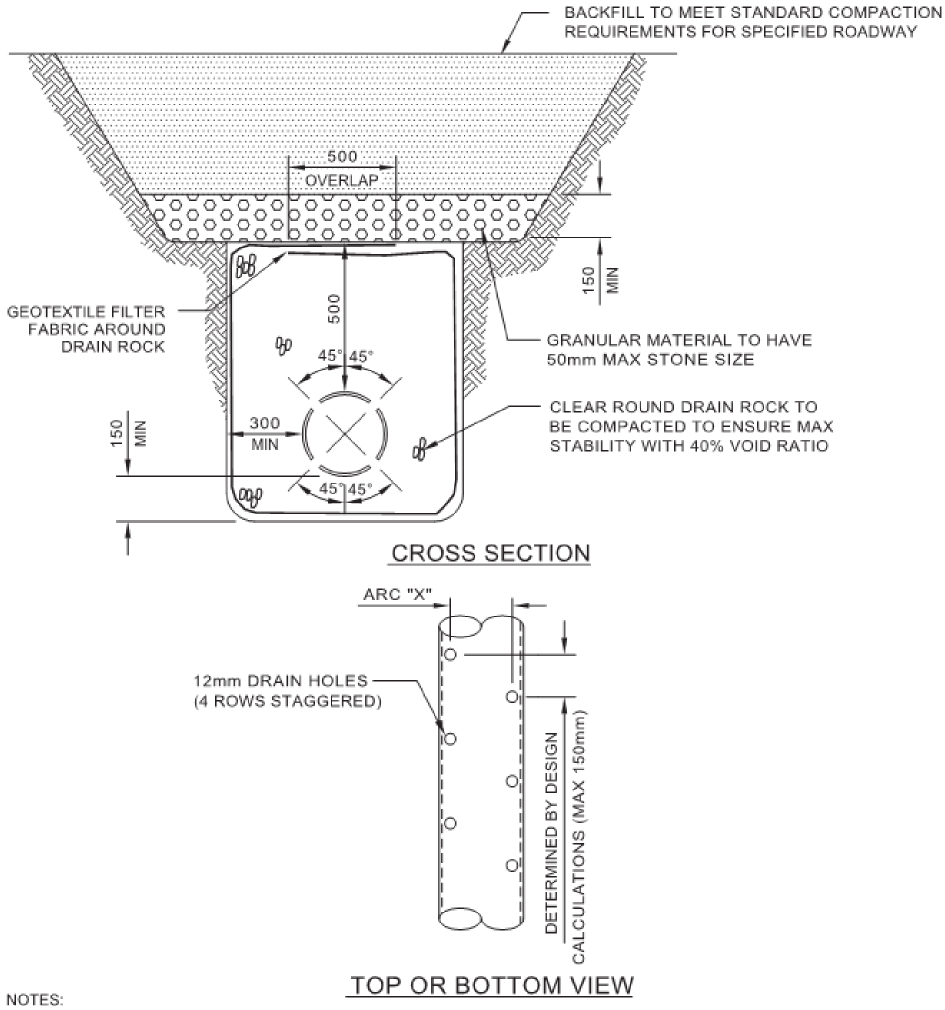
5.2.5. Perforated Pipe Systems

Description

A stormwater conveyance system that features pipe that is perforated along its length and installed in a granular stone bedding that are lined with geotextile fabric which allows infiltration of water into the native soil through the pipe wall as it is conveyed. They can also be referred to as pervious pipe systems, percolation drainage systems or exfiltration systems. A design variation can also include perforated catchbasins, where the catchbasin sump is perforated to allow runoff to gradually infiltrate into the native soil. They are suitable for treating drainage from roofs, walkways, parking lots and low to medium traffic roads, with adequate pretreatment and relatively flat or gentle slopes.

Source: Hatch

Typical Detail



NOTES:
1) USE PERFORATED PVC PIPES
2) FIELD PERFORATION OF PIPE SHALL BE TO THIS STANDARD. FACTORY PERFORATED PIPE MUST BE APPROVED BY THE MUNICIPAL ENGINEER
3) PROVIDE 0.5m MIN OVERLAP FOR LONGITUDINAL OR TRANSVERSE JOINTS IN FABRIC
4) GEOTEXTILE FILTER FABRIC TO BE APPROVED BY THE MUNICIPAL ENGINEER
5) CLEAR DRAIN ROCK TO BE SIZED 20mm
6) ENSURE NO SILT OR CLAY LENS ADJACENT TO TRENCH WALL

Design Guidelines

- *Design Criteria:* Perforated Pipe Systems shall be designed to store and infiltrate or detain and slowly release water quality volume.
- *Building Setback*: Perforated pipe systems shall be setback at least four (4) meters from building foundations to prevent basement flooding and damage during freeze/thaw cycles.[1]

- *Winter Operation*: Perforated pipe systems will continue to function during winter months if the inlet pipe and top of the gravel bed is located below the local maximum frost penetration depth.[1]
- *Site Topography*: Systems cannot be located on natural slopes greater than 15%.
- *Geometry*: Gravel beds in which perforated pipe systems are installed are typically rectangular excavations with a bottom width between 600 and 2400 mm.
- *Water Table*: Provide a 600 mm buffer between the bed bottom and seasonal high groundwater elevation or bedrock.
- *Drainage Area*: Systems typically receive foundation drain water and runoff from roofs, walkways, roads and parking lots from multiple lots. They are typically designed with an impervious drainage area to treatment facility area ratio of between 5:1 to 10:1. Systems are not recommended for industrial sites or commercial developments that present a high risk of groundwater pollution e.g. automobile service yards.
- *Soils:* For sites with native subsoil permeability > 15 mm/hr.
- *Pretreatment:* Pretreatment is required to prevent sediment and debris from entering the system because they can contribute to clogging and failure of the system. Pretreatment options include:

  1) Leaf screens, in-ground devices, and vegetated filter strips or grass swales. Leaf screens are mesh screens installed either on the building eavestroughs or roof downspouts.
  2) In-ground devices such as oil and grit separators, sedimentation chambers, and proprietary separators can be designed to remove large and fine particulates from runoff.
  3) Vegetated filter strips or grass swales can pretreat road and parking lot runoff prior to entering the perforated pipe system.

- *Gravel Storage:* Trenches shall be filled with 50 mm diameter open-graded, clean, double-washed stone with 30-40% void space. The gravel bed shall be designed with gentle slopes between 0.5 to 1%. Depth below the pipe is volume dependent. The depth above pipe shall be 75 to 150 mm.

- *Overflow:* Overflows from the granular filled trench shall backup into manhole connected to conventional storm sewers.
- *Pipe:* Smooth walled PVC perforated pipe wrapped in filter fabric. The minimum size is 200 mm diameter. The size is volume dependent. On-line concrete, clay or plastic trench baffles or other barriers can be installed across the granular filled trench to reduce flow along the system.
- *Geotextile:* Nonwoven needle punched fabric with a recommended typical weight of 203 g/m² shall be installed around the stone reservoir of perforated pipe systems with a minimum overlap at the top of 300 mm.
- *Drain Time:* The maximum acceptable drain down time is 72 hours.

Operations & Maintenance

Table 9 Perforated Pipe Systems Maintenance Recommendations

Task	Description	Frequency
Inspect pretreatment devices	Clean out leaves, debris, and sediment in pretreatment devices	Annually
Inspect and vacuum clean manholes	Inspect manholes to ensure drain down. Remove trash, sediment, and debris from subsurface access and flow control structures	Annually
Jet rodding pipes	Jet-rod conveyance, distribution, and underdrain pipes	Annually

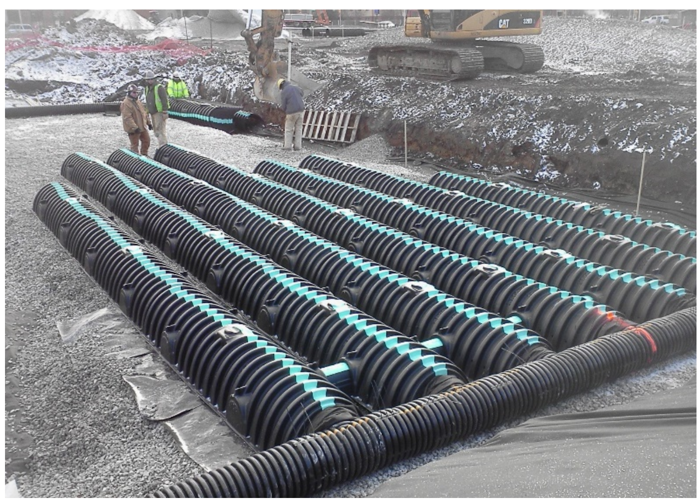
5.2.6. Soakaway/Infiltration Trench

Description

Underground stormwater infiltration practices include soakaways, infiltration trenches, and infiltration chambers. Soakaways are rectangular or circular excavations lined with geotextile fabric and filled with clean stone or other void forming material that receive runoff from a pipe and allow stormwater to infiltrate into the native soils below. Infiltration trenches are rectangular trenches lined with geotextile fabric and filled with clean stone or other void forming material. Infiltration chambers are another design variation on soakaways. They include a range of proprietary manufactured modular structure installed underground, typically under parking or landscaped areas that create large void spaces for temporary storage of stormwater runoff and all ow it to infiltration into the underlying native soil.

Structures typically have open bottoms, perforated side walls and optional underlying granular stone reservoirs. They can be installed individually or in series in trench or bed configurations. They can infiltrate roof, walkway, parking lot and road runoff with adequate pretreatment.[1] The most common types include pre-cast concrete or plastic pits, chambers (manufactured pipes), perforated pipes, and galleys.

Soakaway or Dry Well. Source: NY Septic 1



Subsurface Stormwater Chambers. Source: Cultec

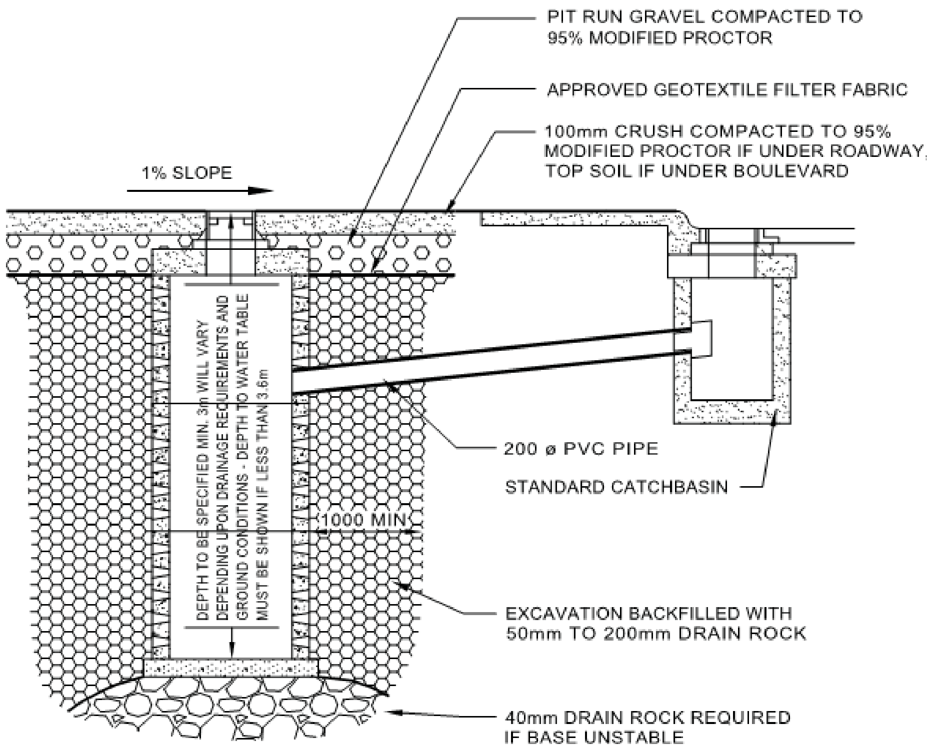
Design Guidelines

- *Design Criteria:* Soakaway/Infiltration Trenches shall be designed to store and infiltrate or detain and slowly release water quality volume.
- *Building Setback*: Perforated pipe systems shall be setback at least four (4) meters from building foundations to prevent basement flooding and damage during freeze/thaw cycles.[1]

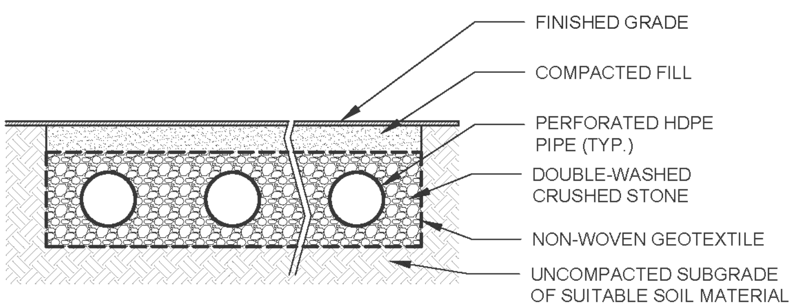
- *Winter Operation*: Perforated pipe systems will continue to function during winter months if the inlet pipe and top of the gravel bed is located below the local maximum frost penetration depth.[1]
- *Site Topography*: Systems cannot be located on natural slopes greater than 15%.
- *Geometry*: Can be designed in a variety of shapes. Infiltration trenches are typically rectangular excavations with a bottom width between 600 and 2400 mm. Facilities shall have level bed bottoms.
- *Water Table*: Provide a 600 mm buffer between the bed bottom and seasonal high groundwater elevation or bedrock.
- *Drainage Area*: Systems typically receive foundation drain water and runoff from roofs, walkways, roads and parking lots from multiple lots. They are typically designed with an impervious drainage area to treatment facility area ratio of between 5:1 to 20:1. A maximum ratio of 10:1 is recommended for facilities receiving road or parking lot runoff. Systems are not recommended for industrial sites or commercial developments that present a high risk of groundwater pollution e.g. automobile service yards.
- *Soils:* For sites with native subsoil permeability > 15 mm/hr.
- *Pretreatment:* Pretreatment is required to prevent sediment and debris from entering the system because they can contribute to clogging and failure of the system. Pretreatment options include:

    1) Leaf screens, in-ground devices, and vegetated filter strips or grass swales. Leaf screens are mesh screens installed either on the building eavestroughs or roof downspouts.
    2) In-ground devices such as oil and grit separators, sedimentation chambers, and proprietary separators can be designed to remove large and fine particulates from runoff.
    3) Vegetated filter strips or grass swales can pretreat road and parking lot runoff prior to entering the perforated pipe system.

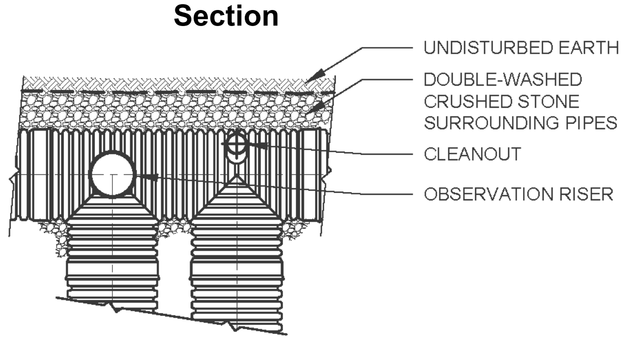
- Monitoring Wells: A capped vertical standpipe consisting of an anchored 150 mm diameter perforated pipe with a lockable cap installed to the bottom of the facility is recommended for monitoring the length of time required to fully drain the facility between storms. Manholes and inspection ports shall be installed in infiltration chambers to provide access for monitoring and maintenance activities.
- *Stone Reservoir:* Soakaways and infiltration trenches shall be filled with 50 mm diameter open-graded, clean, double-washed stone with 30-40% void space.
- *Overflow:* Overflows from the granular filled trench shall backup into manhole connected to conventional storm sewers.
- *Pipe:* Smooth walled PVC or HDPE perforated pipe with a minimum diameter of 150 mm.
- *Geotextile:* Nonwoven needle punched fabric with a recommended typical weight of 203 g/m² shall be installed around the stone reservoir of perforated pipe systems with a minimum overlap at the top of 300 mm.
- *Drain Time:* The maximum acceptable drain down time is 72 hours.



Typical Soakaway Section



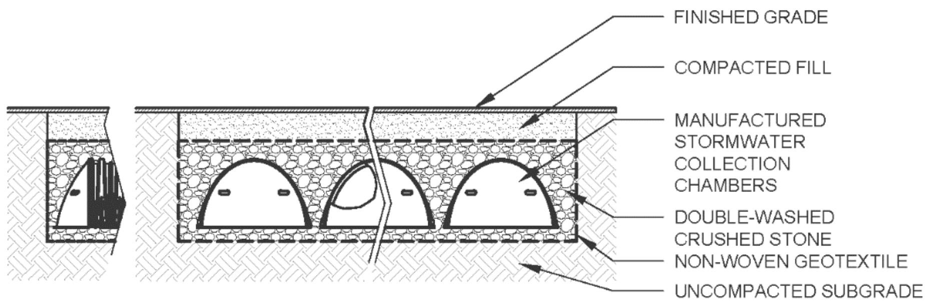
Section



NOTE:PIPE SPACING, COVER, BEDDING, FILL, SUBGRADE SUITABILITY, AND PIPE AND STONE SIZE TO BE DETERMINED BY ENGINEER AND BASED ON MANUFACTURER RECOMMENDATIONS.

Plan

Typical Pipe Infiltration Detail



Typical Chamber/Arch Infiltration Detail

Operations & Maintenance

Table 10 Soakaway/Infiltration Trench Maintenance Recommendations

Task	Description	Frequency
Inspect pretreatment devices	Clean out leaves, debris, and sediment in pretreatment devices	Annually
Inspect and vacuum clean manholes	Inspect manholes to ensure drain down. Remove trash, sediment, and debris from subsurface access and flow control structures	Annually
Jet rodding pipes	Jet-rod conveyance, distribution, and underdrain pipes	Annually

5.2.7. Permeable Pavement

Description

Permeable pavements, an alternative to traditional impervious pavement, allow stormwater to pass through the surface and into an aggregate reservoir where it is infiltrated into the underlying native soil or temporarily detained. They can be used for low traffic roads, parking lots, driveways, pedestrian plazas and walkways. Permeable pavement is ideal for sites with limited space for other stormwater management practices[1]. Examples of permeable pavement types include:

- Plastic or concrete grid systems (i.e. grid pavers);

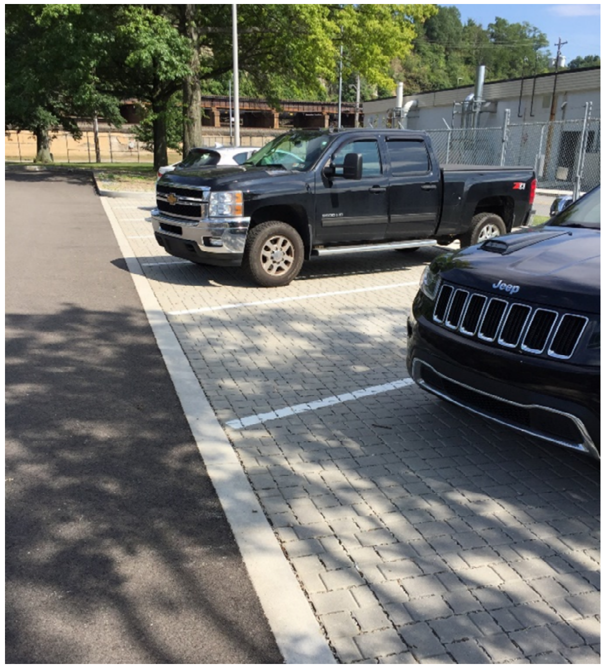
- Porous asphalt;

Source: Hatch

- Pervious concrete; and

Source: Heritage Bormanite

- Permeable interlocking concrete or clay pavers (i.e. block pavers);



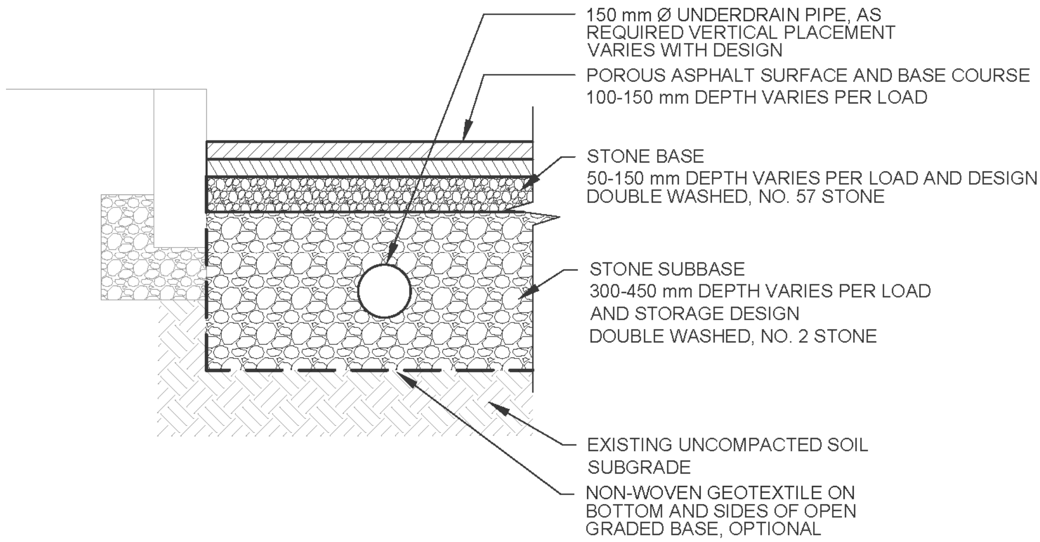
Source: Hatch

Design Guidance

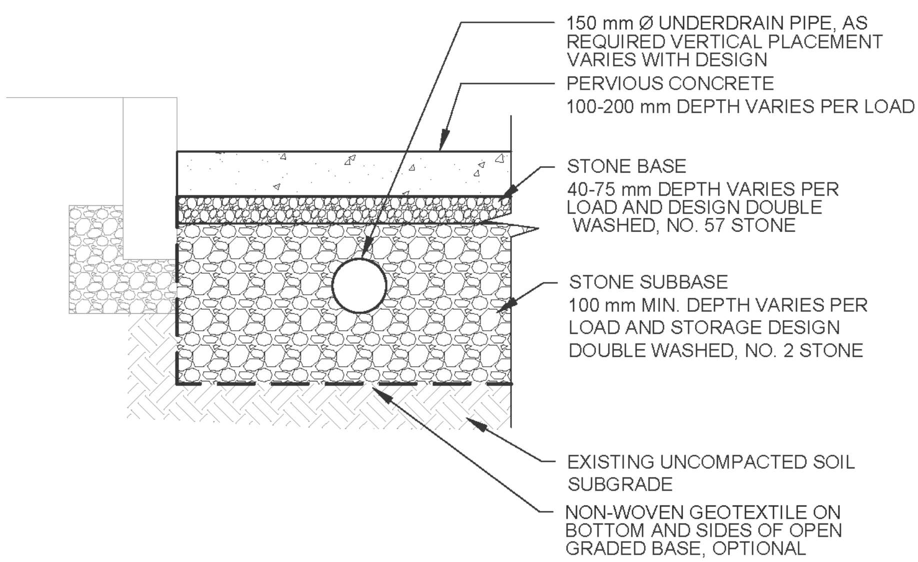
- *Design Criteria:* Permeable Pavements shall be designed to store and infiltrate or detain and slowly release water quality volume.
- *Open Graded Base and Subbase*: Depth varies by design application. Provide an open-graded, clean, double-washed aggregate subbase with minimum 40% void space.
- *Clogging*: Susceptibility to clogging is the main concern for permeable paving systems. The bedding layer and joint filler shall consist of 2.5 mm clear stone or gravel rather than sand. Key strategies to prevent clogging are to ensure that adjacent pervious areas have adequate vegetation cover and a winter maintenance plan that does not include sanding. [1]
- *Structural Stability*: Adherence to design guidelines for pavement design and base courses will ensure structural stability. In most cases, the depth of aggregate material required for the stormwater storage reservoir will exceed the depth necessary for structural stability. Reinforcing grids can be installed in the bedding for applications that will be subject to very heavy loads.[1]

- *Vehicle Traffic*: Permeable pavement is not typically used in locations subject to heavy loads.[1] Permeable pavement is typically used at location with low to moderate vehicular traffic.
- *Overflow*: A secondary overflow for the system such as an overflow edge or inlets as well as an outlet pipe to storm drain or swale system to convey larger storms must be included.
- *Winter Operations:* Sand or other granular materials shall not be applied as anti-skid agents during winter operation because they can quickly clog the system. Winter maintenance practices shall be limited to plowing, with de-icing salts applied sparingly.[1]
- *Site Topography:* The slope of the permeable pavement surface shall be at least 1% and no greater than 5%. The bottom of the aggregate storage reservoir shall be flat. Subsurface check dams and terracing of the bottom reservoir may be required.
- *Water Table*: Provide a 600 mm buffer between the bed bottom and seasonal high groundwater elevation or bedrock.
- *Soils*: For sites with native subsoil permeability > 15 mm/hr, the system may be designed with no underdrain for full infiltration. For pavements designed for partial infiltration, where native soil permeability is > 1 and < 15 mm/hr, a perforated pipe underdrain shall be placed near the top of the granular stone reservoir. Partial infiltration and no infiltration designs for sites with native subsoil permeability < 1 mm/hr can include a flow restrictor assembly on the underdrain to optimize infiltration with desired. Do not place stone bed on compacted fill.
- *Drain down:* Drain down time for the aggregate reservoir shall be between 24-72 hours.
- *Drainage Area and Runoff Volume:* Permeable pavement systems can be designed to receive runoff from adjacent impervious paved surfaces. For example, the parking spaces of a parking lot can be permeable pavement while the drive lanes are impervious asphalt. The storage layer under the permeable pavement must be sized to accommodate runoff from the pavement itself and any impermeable areas draining to it. Systems are not recommended for industrial sites or commercial developments that present a high risk of groundwater pollution e.g. automobile service yards.

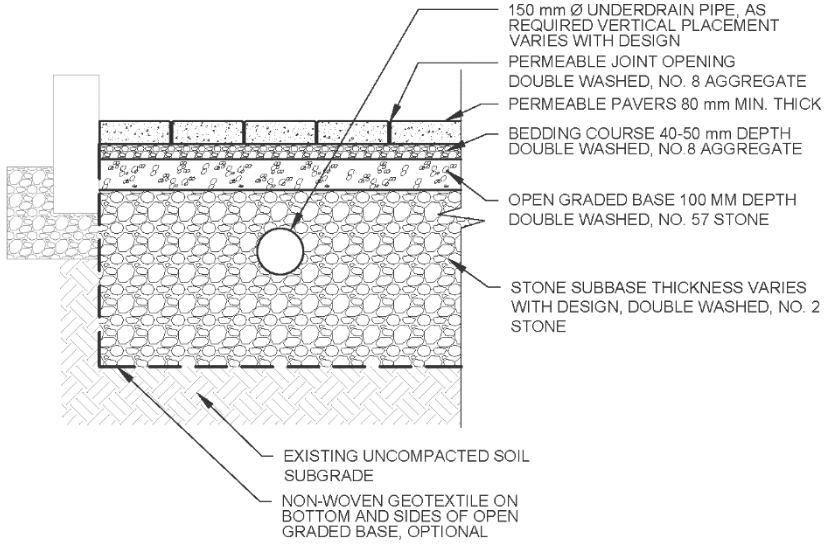
- *Setbacks from Buildings*: Permeable pavement shall be located downslope from building foundations. If the pavement does not receive runoff from other surfaces, no setback is required from building foundations provided the foundations have piped drainage at the footing.[3] Otherwise, a minimum setback of four (4) meters down-gradient from building foundations is recommended.[2]



Typical Porous Asphalt Section



Typical Pervious Concrete Section



Typical Permeable Paver Section

Operations & Maintenance

Table 11 Permeable Pavement Maintenance Recommendations

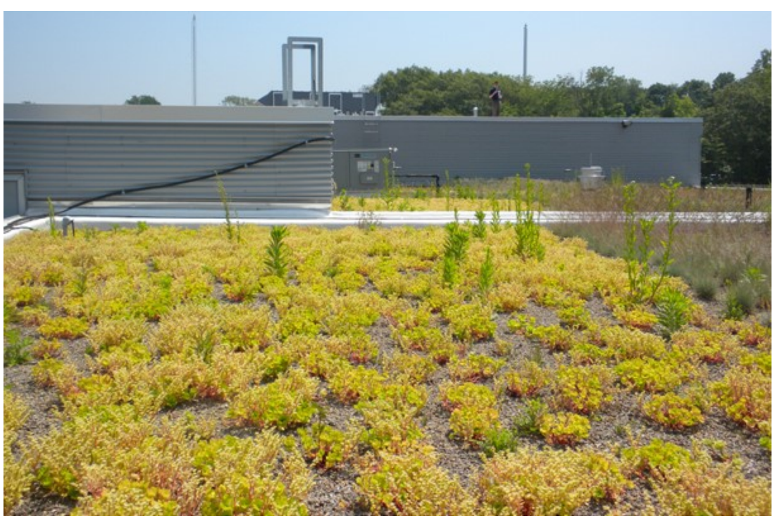
Task	Description	Frequency
Remove trash and leaf debris	Remove trash. Sweep or use a leaf blower to remove leaf litter and sediment to prevent surface clogging and ponding.	3 times per year
Remove fine sediment and debris	Vacuum surface with regenerative air sweeper or commercial vacuum sweeper.	Annually
Vacuum clean structure	Remove trash/sediment/organic debris from inlet and outlet control structures.	Annually
Inspect underdrain cleanouts	Inspect underdrain cleanouts and if necessary, jet-rod pipes.	Annually
Replenish aggregate	After vacuuming surface replenish aggregate in joint of permeable pavers.	1-2 times per year
Mow and weed vegetation	Mow grass and manually remove. weeds in permeable paver or grid systems.	As needed

5.2.8. Green Roof

Description

A green roof is a lightweight vegetated system consisting of water proofing material, a drainage layer, a filter layer, and a growing medium that support living vegetation. Green roofs can be installed on small slanting residential to large commercial roofs and can be installed on only a portion of the roof. There are two types of green roofs: intensive and extensive. Intensive green roofs have deeper growing medium depths (greater than 300 mm) to support larger plants and trees. Extensive green roofs have a relatively shallow growing medium thickness (less than 300 mm) with low growing, drought tolerant plants. Extensive green roofs are more common. Guidance in this section focuses on extensive green roof design.

Source: Hatch



Source: Hatch

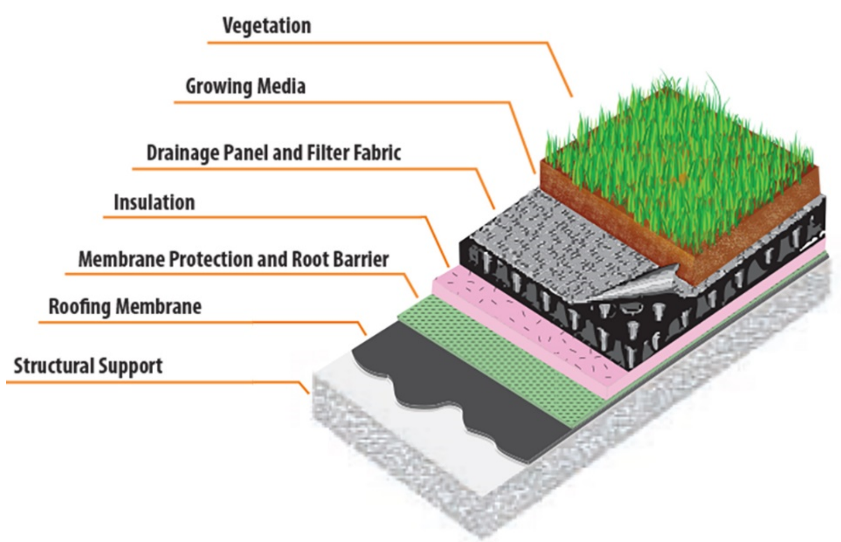
Design Guidelines

Source: Hatch

- Canada does not have official green roof standards. Until such standards are published, the German FLL guidelines and test procedures represent the only comprehensive standards for green roof design, installation and maintenance.[5]
- *Structural Requirements*: The roof structure must be strong enough to hold the additional weight of the green roof. The load-bearing capacity of the roof must be evaluated by a licensed professional, and the design must comply with building code requirements.[4]
- *Roof Slope*: Green roofs are not recommended for roofs with less than 2% slope and above a 22° (40%) slope. Roofs with slopes over 11° angle (20%) require anti-shear layers or anchorage and erosion control systems.[6]
- *Drainage Area and Runoff Volume*: Green roofs reduce the effective impervious cover and are typically sized based on the available roof area as opposed to treatment volume requirements.[1] Green roofs are designed to capture precipitation falling directly onto the roof surface. They are not typically designed to receive runoff diverted from other source areas.[2]
- *Drainage Layer and Overflow:* A method of drainage must be provided. Once the porous soil media is saturated, all runoff shall be directed to a conventional roof storm drain system to manage excess runoff from the roof. Roof drains must connect to an approvable discharge location.
- *Waterproofing and Root Barriers:* All conventional commercial waterproofing materials may be used. A root barrier is sometimes required in addition to waterproofing material. Some waterproofing materials also act as a root barrier
- Growing Media: Depth of at least 100 mm is recommended. The medium must support the chemical, biological, and physical needs of the plants. Designers are encouraged to use a medium with significant water-holding capacity to maximize stormwater retention.

The medium shall be an unconsolidated mixture of mineral aggregate such as screened pumice and sandy loam, and organic matter such as aged compost or fiber compost.[4]

- *Landscaping*: A qualified landscape architect shall be consulted when choosing plant material. For extensive systems, plant material shall be non-monoculture, drought resistant, native or adaptive varieties of grass and sedum. Root size and depth shall also be considered to ensure that the plant will stabilize the shallow depth of growing medium.[1]
- *Irrigation:* Provide a hose bib for manual watering during establishment if no automatic irrigation system is planned.
- *Access:* Provide access paths for maintenance of the green roof and roof fixtures.



Source: City of Toronto, Green Roof Construction Standard Supplementary Guidelines

Typical Section

Operations & Maintenance

More intensive maintenance is required in the first two to three years of the green roof as plants are becoming established such as watering, weed removal, and replacement of dead plants. Typical maintenance after the establishment period is outlined below.

Table 12 Green Roof Maintenance Recommendations

Task	Description	Frequency
Weeding	Remove volunteer seedlings of trees and shrubs.	2 times per year
Inspect drains and membrane	The drains shall be kept clear of sediment and debris. Inspect membrane for any leaks or tears.	2 times per year
Debris and dead vegetation removal	Debris and bird feces shall be removed.	2 times per year

5.2.9. Rainwater Harvesting

Description

Rainwater harvesting is the process of intercepting, conveying and storing rainfall for future use. The rain that falls upon a catchment surface, such as a roof, is collected and conveyed into a storage tank. Storage tanks range in size from rain barrels for residential land uses (typically 190 to 400 liters in size), to large cisterns for industrial, commercial and institutional land uses. A typical pre-fabricated cistern can range from 750 to 40,000 liters in size. With minimal pretreatment (e.g., gravity filtration or first flush diversion), the captured rainwater can be used for outdoor non-potable water uses such as irrigation and pressure washing, or in the building to flush toilets or urinals. It is estimated that these applications alone can reduce household municipal water consumption by up to 55%.[1]

Design Guidelines

Source: Hatch

Source: Texas A&M Agrilife Extension

Systems can be designed for year-round outdoor and indoor uses. In cold climate regions these systems must be located underground below the local frost penetration depth or indoors in a temperature-controlled environment to prevent freezing. Other systems are designed for outdoor usage only and are located above-ground or underground and require decommissioned annually prior to the onset of freezing temperatures.[0]

- *Plumbing Codes*: Local plumbing codes must be consulted for the requirements for the use of harvested rainwater for toilet and urinal flushing.
- *Indoor Use*: Separate plumbing, pumps, pressure tanks, and backflow preventers are necessary for indoor use of harvested water.
- *Standing Water and Mosquitoes:* Designers shall provide screens on inlets and overflow outlets to prevent mosquitoes and other insects from entering the system.
- *Drawdown Between Storms:* The extent to which cisterns reduce runoff and peak flows depends on use of the captured rainwater between storms, so that capacity exists to capture a portion of the next storm. Water demand estimations shall be submitted for review along with other stormwater management system design documents.[1]
- *Setbacks from Buildings*: Rainwater harvesting system overflow devices shall be designed to avoid causing ponding or soil saturation within three (3) meters of building foundations. Storage tanks must be watertight to prevent water damage when placed near building foundations.
- *Catchment Areas*: Roofs are used as the catchment surface for rainwater harvesting systems.
- *Collection and Conveyance*: The eavestroughs, downspouts and pipes that channel runoff into the storage tank
- *Pretreatment*: Pretreatment is required to remove dust, leaves, and other debris that accumulates on roofs and prevents clogging within the rainwater harvesting system. Different levels of pretreatment shall be provided, depending on how the harvested water will be used. Pretreatment includes eavestrough or downspout filters, first flush diverters, in-ground filters, and in-tank filters.
- *Storage Tank*: Cisterns may be ordered from a manufacturer or can be constructed on site from a variety of materials including fiberglass, polypropylene, wood, metal and concrete.

- *Distribution*: Most distribution systems are gravity fed or operated using pumps to convey harvested rainwater from the storage tank to its destination
- *Access:* Provide access to the storage tank for cleaning, inspection, and maintenance. Tank shall be secured to for safety and unwanted access.
- *Overflow*: An overflow system must be included in the design if multiple storms occur in succession and fill the rainwater storage. The overflow system can be directly connected to a storm sewer with the incorporation of a backflow preventer or can overflow to a pervious area or infiltration facility.

Operations & Maintenance

Table 13 Rainwater Harvesting Maintenance Recommendations

Task	Description	Frequency
Inspect and remove debris	Inspect the cistern or rain barrels, downspout or conveyance system, overflow, and pretreatment devices for obstructions, leaks, or damage. Remove debris.	2 times per year
Drain and disconnect system	Drain system prior to winter and disconnect the system from roof leader if water is not intended to be used in the winter.	Annually
Apply larvicide and other chemicals	Apply larvicide to prevent mosquitoes and apply other chemical to kill bacteria present in the system	As needed.

5.2.10. Summary

Every development and site combination require customized LID solutions. The table below illustrates typical applications of LID practices

Table 14 Typical LID Practice Applications

Development Type / LID Practice	Park / Open Space	Surface Parking Lots	Low Volume Roads	Low Density Residential	High Density/ Commercial*/ Industrial*/ Institutional
Enhanced Grass Swale	x	x	x	x	x
Dry Swale	x	x	x	x	x
Rain Garden	x			x	
Bioretention Cell	x	x	x	x	x
Perforated Pipe System	x	x	x	x	x
Soakaway / Infiltration Trench	x	x	x	x	x
Permeable Pavement		x		x	x
Green Roof				x	x
Rainwater Harvesting	x			x	x

*Practices that relay on infiltration may be prohibited in industrial and some types of commercial sites.

6. References

1. Toronto and Region Conservation Authority (TRCA). 2010. *Low Impact Development Stormwater Management Planning and Design Guide.* Toronto, ON.
2. Metro Vancouver. 2012. *Stormwater Source Control Design Guidelines.* Vancouver, BC.
3. Smith, David R. 2011. *Permeable Interlocking Concrete Pavements: Design, Specifications, Construction, Maintenance.* Fourth Edition. Interlocking Concrete Pavement Institute (ICPI). Chantilly, Virginia.
4. City of Portland. 2016. *Stormwater Management Manual.* Portland, OR.
5. FLL. 2002. *Guidelines for Planning, Execution and Upkeep of Green-roof Sites*. Bonn.
6. Office of the Chief Building Official, Toronto Building. *Toronto Green Roof Construction Standard: Supplementary Guidelines.* Toronto, ON.

Appendix A: Plan Requirements and Details

Stormwater Management Plan

Prior to receiving development approval, the developer is required to prepare a stormwater management plan based on the following requirements:

- The stormwater management plan shall apply to the entire area of land to developed;
- The stormwater management plan shall include a drainage plan to address all drainage patterns within the development area and shall prescribe a method for the proper drainage and collection of stormwater based on the full development of the site;
- The stormwater management plan shall include a grading plan to address the conveyance of all surface runoff from the developed development area to a stable outlet or established drainage area in accordance with this guideline;
- The stormwater management plan shall meet all specific requirements under this guideline;
- The stormwater management plan shall be conducted by a Professional Engineer and shall be stamped as such and shall be subject to the approval of Nova Scotia Environment and the Town/

Further, the stormwater management plan shall address the following matters:

- Provide for safe and convenient use of streets, sidewalks, walkways and lots following a storm;
- Protect structures and property from damage due to a major storm event;
- Preserve natural watercourses and other natural features and minimize the long-term effect of development on receiving watercourses and groundwater; and;
- Convey stormwater from upstream and on-site sources, and mitigate the adverse effects of such flow on downstream properties.

All paved public roads that do not have a buried stormwater system, shall be designed and constructed with an open-ditch stormwater drainage system in accordance with this guideline.

Further, the developer shall be required to:

- Provide at no cost to the Municipality, a drainage corridor to the nearest watercourse or public road, where such corridors are specified in the Stormwater Management Plan; and
- Transfer to the Municipality, land, including drainage corridors, that may be necessary to operate and maintain stormwater systems.

Lot Grading Plan

Ground Surface

The ground elevation adjacent to any foundation walls must be at least 150 mm below the top of the foundation wall.

All surfaces must slope away from the building as follows:

- Front yard – the front yard shall be continuously graded to drain away from the building towards the street.
- Back yard – the back yard shall be graded to drain away from the building for a minimum distance of 3 metres with a minimum drop of 150 mm.

- Side yard – where permitted by applicable land use by-law and/or by development agreement, the side yards shall be graded to drain away from the building a minimum distance of 1.2 metres with a minimum drop of 150 mm.

All landscaped lot surfaces shall have a minimum slope of 2%, unless otherwise provided for in this Schedule. Grades are encouraged to be, where possible, steeper than the minimum.

The maximum slope on any lot surface shall be 3:1 (H:V) unless constructed on in situ rock or unless otherwise approved by the Town. Certification of slope stability by a geotechnical engineer may be required for approval as well as consideration of other issues such as maintenance and erosion. The top and bottom of banks shall be rounded for convenient maintenance. Notwithstanding the foregoing, a suitably graded slope is required with surface treatment to provide for long term stability.

Where areas are disturbed, stabilization is to be provided to prevent erosion.

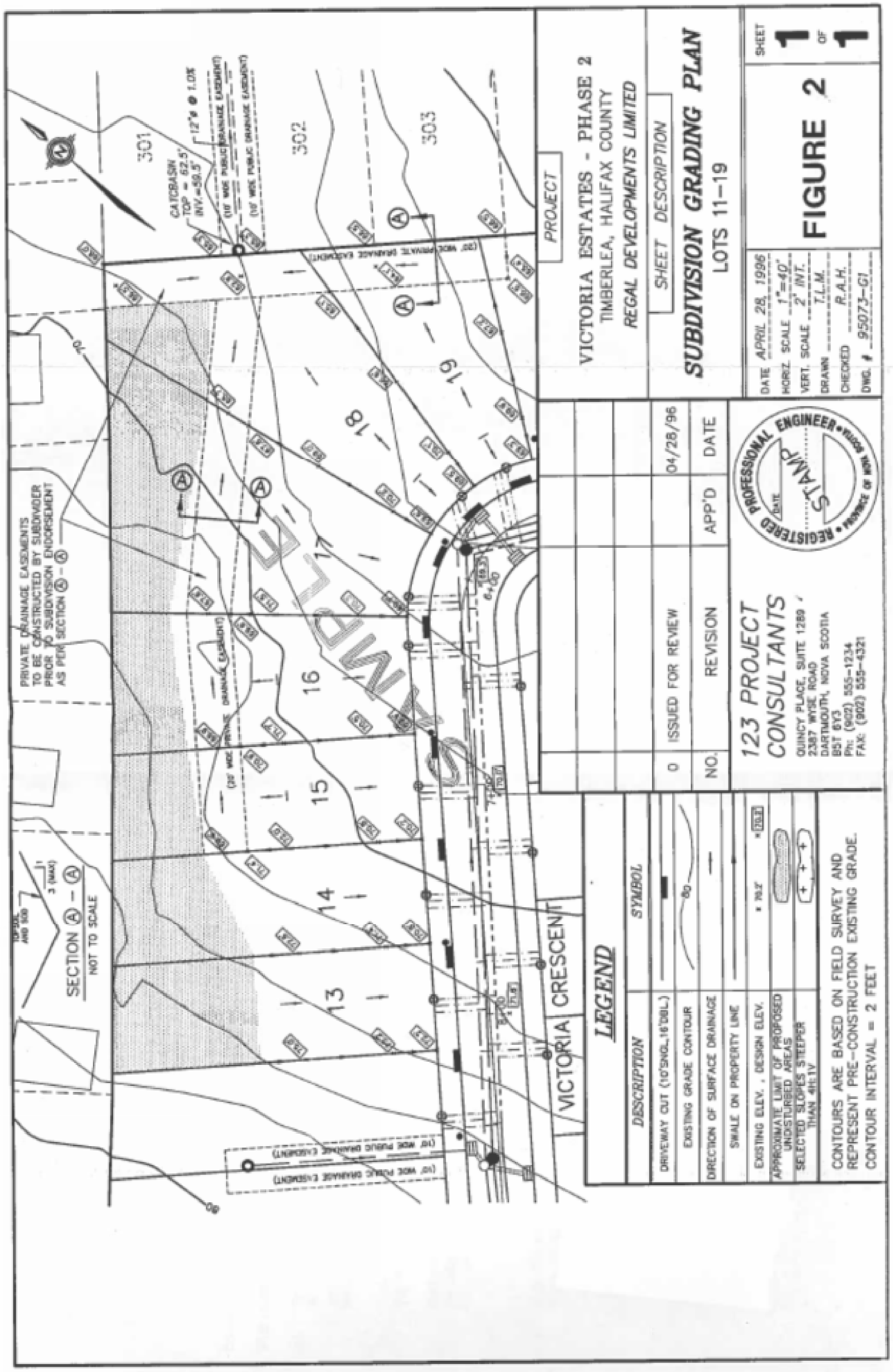
<u>Driveways/parking/Open Areas</u>

The portion of the driveway within the front yard shall be graded to drain away from the building towards the street and to prevent the direct discharge of water onto adjacent property.

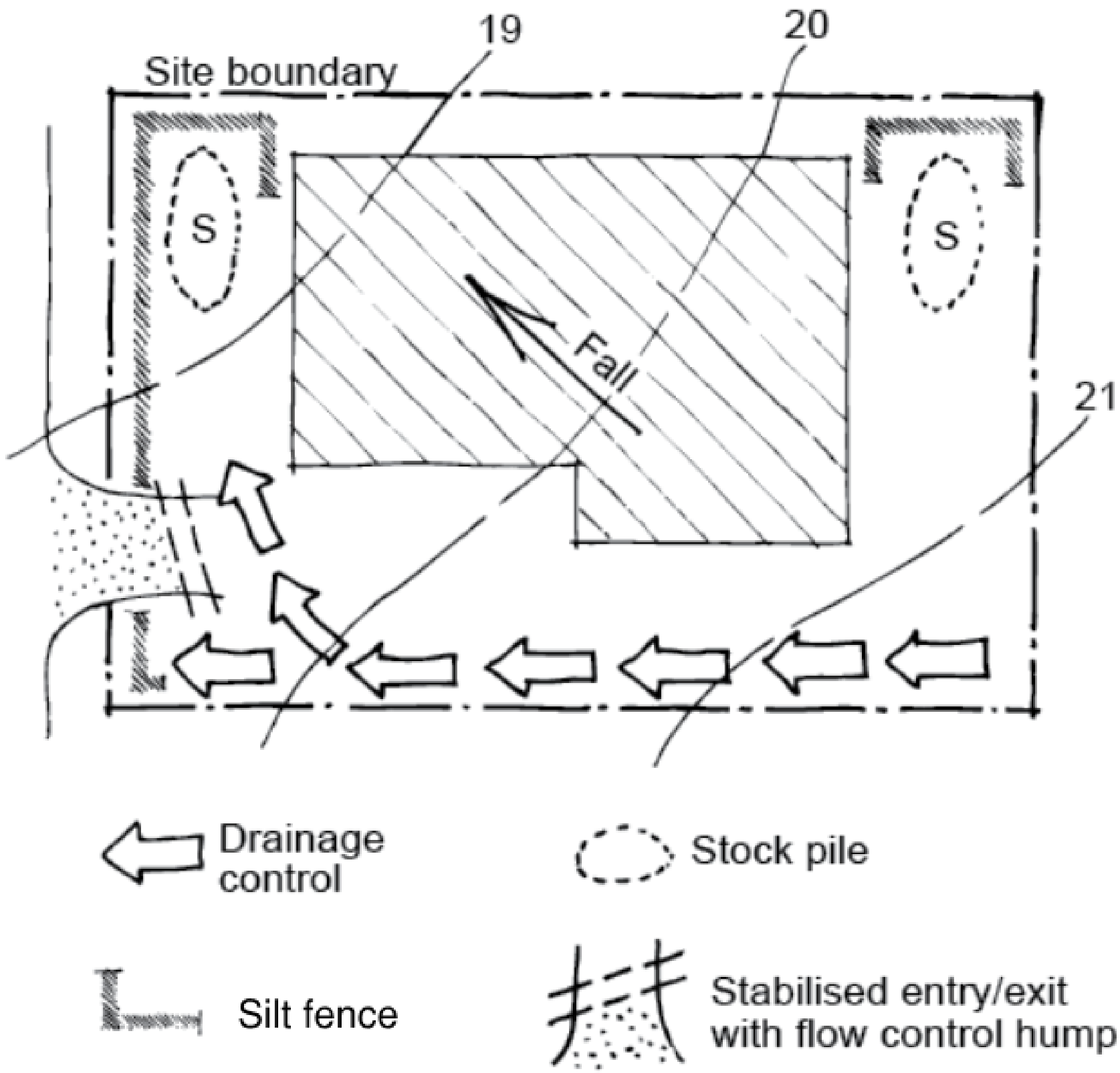
Driveway slopes shall not be less than 2%.

For paved or impervious areas greater than 100 square metres, additional information and design requirements with respect to grading and drainage may be required.

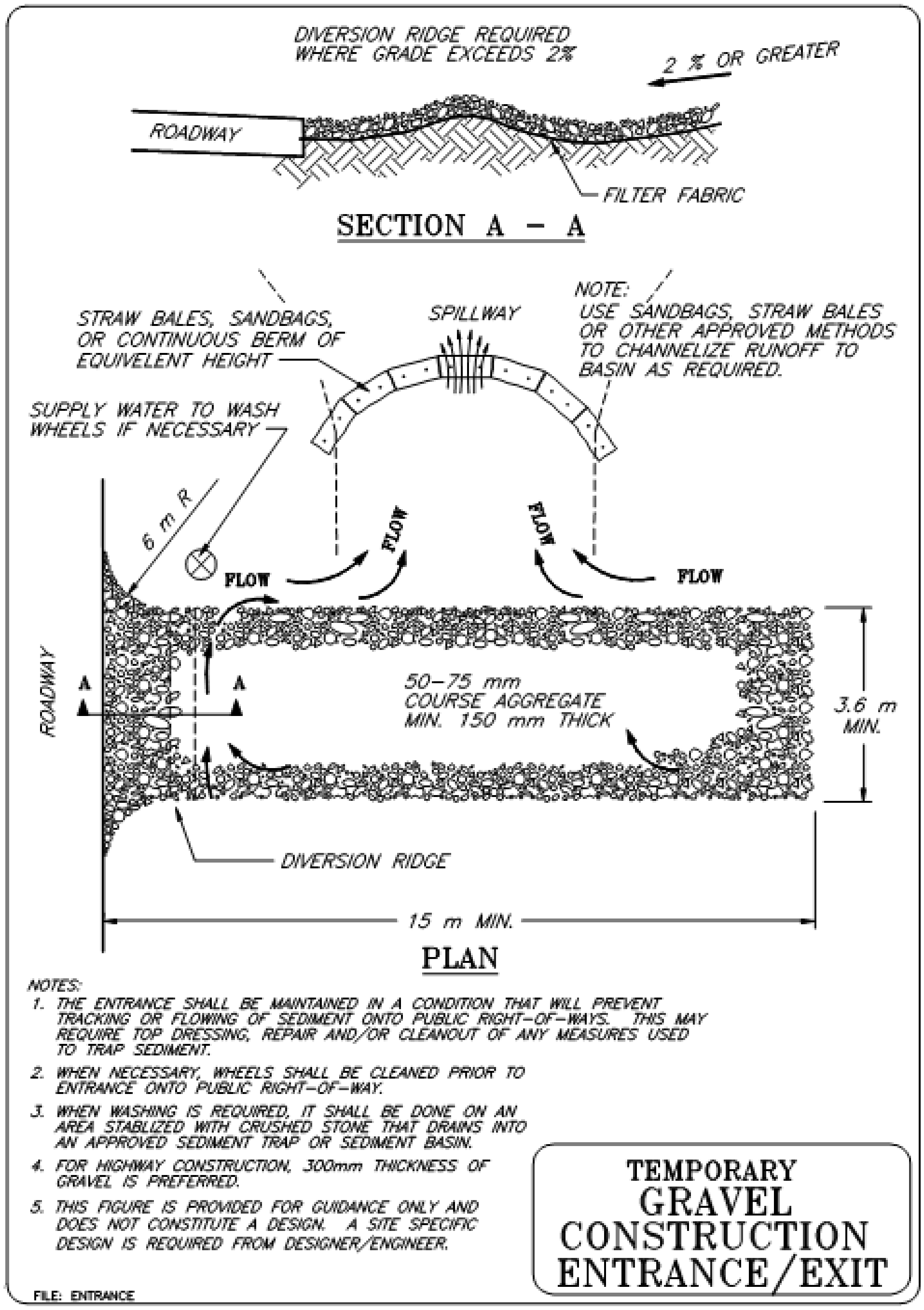
Lot Grading Plan



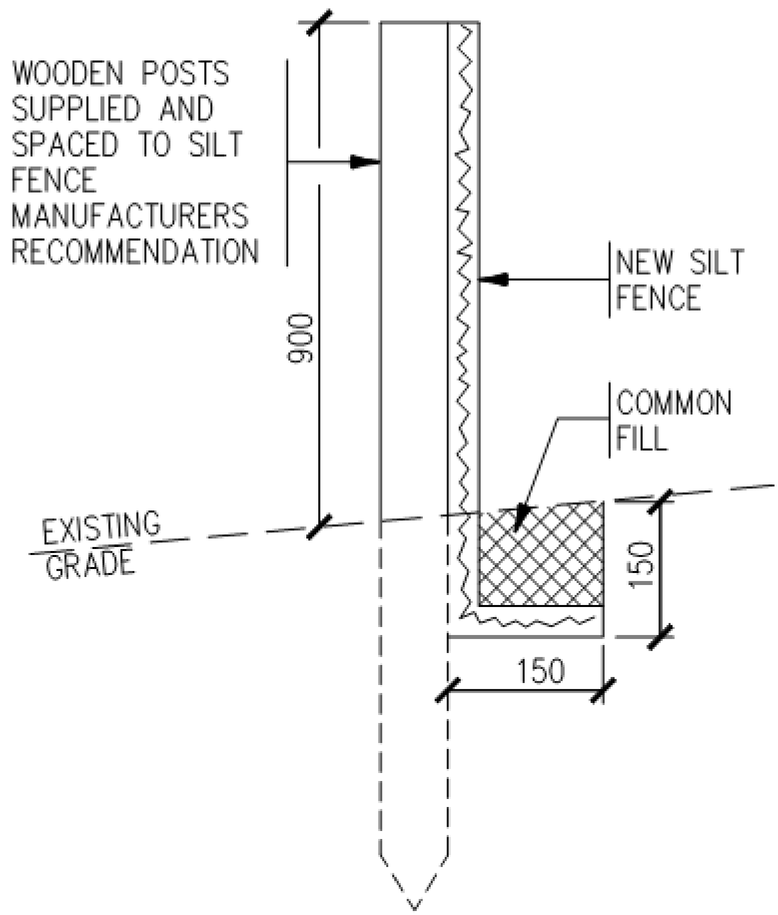
Erosion and Sediment Control Plan – Concept



Stabilized site access



Silt Fence



SILT FENCE DETAIL

N.T.S.