Design Criteria for Green Infrastructure in the Right-of-Way

September 2021

TORONTO

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City of Toronto *Design Criteria for Green Infrastructure in the Right-of-Way* manual:

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Introduction

The *Design Criteria for Green Infrastructure in the Right-of-Way* manual has been written for City of Toronto staff and consulting engineers who will be working on green infrastructure projects in the public right-of-way. The purpose of this manual is to ensure there is consistency in the approach to green infrastructure planning and design. This manual will also help ensure that the information provided by staff to third party green infrastructure stakeholders is consistent throughout all offices.

This manual is written for City staff and consulting engineers working on capital improvement projects and for consulting engineers working for the development industry preparing engineering designs and drawings for private developments that contain future City right-of-ways.

This manual provides the necessary criteria in the design of green infrastructure within the right-of-way. It is intended to be used in conjunction with the City's standard drawings and specifications for green infrastructure in the right-of-way, *Lifecycle Activities for Green Infrastructure in the Right-of-Way* manual, and *Community Engagement for Green Infrastructure in the Right-of-Wa*y manual in additional to external guidelines referenced in the subsequent sections. This manual should also be read in conjunction with the City's *Green Streets Technical Guidelines* and Chapter 3, *Storm Sewers* of the *Design Criteria for Sewers and Watermains* manual.

What is Green Infrastructure and why do we need it?

In alignment with the Toronto's Official Plan, Green Infrastructure (GI) means natural and human-made elements that provide ecological and hydrological functions and processes while also delivering multiple co-benefits. Green infrastructure may include components such as natural heritage features and systems, parklands, stormwater management systems, street trees, urban forests, natural channels, permeable surfaces, and green roofs.

Within the context of this manual, GI systems described are intended for location within the Toronto's right-of-way (ROW).

As the city continues to grow and be developed, more and more of the city's natural land is transformed into largely impervious built environments. Increasing imperviousness results in greater amounts of stormwater runoff being generated, higher pollutant loads being entrained by urban runoff and groundwater being depleted. Furthermore, the effects of climate change are imposing additional stress and strain on our urban drainage systems and ecosystems through more extreme weather systems such as high intensity rainfall and extended drought periods. There is a therefore growing demand to adopt urban water management practices that protect, restore, or mimic the natural water cycle.

The incorporation of green infrastructure into the City's right-of-ways is an effective way of meeting stormwater management technical performance requirements while achieving greater system resilience and generating multiple co-benefits. Right-of-way GI can manage stormwater generated by our streetscape close to its source, reduce stress on existing infrastructure, contribute toward the mitigation of basement flooding, reduce downstream erosion, manage the quality and quantity of runoff that enters our piped systems, while simultaneously co-benefiting streetscapes with increased tree canopy, vegetated landscape, habitat for bio-diversity and points of public interest. The GI systems discussed in this manual are as follows:

- street trees in stormwater tree trenches (STT)
- bioretention systems such as curb extensions, bioretention planters, raingardens
- bioswales
- enhanced grass swales
- green gutters
- filter strips
- permeable pavements such as porous asphalt, pervious concrete, and permeable interlocking concrete pavers
- infiltration trenches

A detailed description of each system is available in Chapter 6, *Green Infrastructure System Design Criteria*.

What are GI Design Criteria?

Design criteria set out the explicit goals that must be met in order for the installation and operation of a GI system to be considered successful. Design criteria presented in this manual will assist consultants, developers, and owners with the successful planning, siting and design of GI systems.

Related Manuals

The following manuals and documents should be used in conjunction with this manual:

- Design Criteria for Sewers and Watermains
- Wet Weather Flow Management Guidelines
- Green Streets Technical Guidelines
- T-850 Series standard drawings and associated specifications
- City of Toronto Tree Protection Policy and Specifications for Construction Near Trees

What This Manual Contains

Chapter 1 – Policies, Regulations and Guidelines – covers the municipal, provincial, and federal requirements.

Chapter 2 – Toronto's Physical Characteristics – covers the local environmental conditions such as climate, topography, and geology.

Chapter 3 – Green Infrastructure Planning and Siting – covers initial field investigations required to site GI, and preliminary siting considerations for new construction and retrofit projects.

Chapter 4 – Design Considerations – covers design considerations for siting GI in the city such as cold weather, water quality, water quantity, hydrological requirements, and urban integration.

Chapter 5 – Design Criteria for Common Elements – covers design criteria for elements that are common across several GI systems including vegetation, planting, growing media, soil amendment, inlets, outlets, and underdrains.

Chapter 6 – Green Infrastructure System Design Criteria – covers design criteria specific to each GI system.

Glossary – provides an alphabetical list of technical terms relating to the design of green infrastructure systems and their definitions.

Index – provides an alphabetical list of topics, keywords and synonyms used in this manual.

Appendix A – Green Streets Project Selection Process

Chapter 1 – Policies, Regulations and Guidelines

There are several existing federal, provincial, and municipal policies and regulations that govern stormwater management and construction within the city of Toronto. This section provides an overview of the policies, guidelines, and regulations that impact the design and construction of GI in the right-of-way. When planning and designing GI, the following regulations and associated authorities should be consulted:

Federal Regulations

Navigable Waters Protection Act

This Act prohibits construction in navigable waters and the dumping of waste that may interfere with navigation.

GI in right-of-way is unlikely to be located in areas where this Act would be invoked; however, if the siting does invoke the Act, the GI will be treated in the same manner as conventional stormwater management infrastructure.

The Federal Fisheries Act

The purpose of this Act is to ensure the conservation and protection of fish and fish habitats.

Under the Act, GI in right-of-way will be treated similarly to conventional stormwater management infrastructure.

Canadian Environmental Protection Act

This Act is intended to promote sustainable development through pollution prevention and enforce the protection of the environment and human life and health from the risks of toxic substances.

GI in right-of-way that discharges stormwater runoff to receiving water bodies requires the same approvals as conventional stormwater management infrastructure.

Source Protection Policies (Clean Water Act)

This Act ensures that existing and future drinking water sources remain protected through the implementation of preventative measures.

GI in right-of-way that discharges stormwater runoff to receiving water bodies requires the same approvals as conventional stormwater management infrastructure.

Provincial Regulations

Conservation Authorities Act (R.S.O. 1990, last amended 2019)

This Act establishes authority of programs and services that further the conservation, restoration, development and management of natural resources on a per watershed basis.

Planning Act (R.S.O 1990, last amended 2020)

This Act establishes rules for land use planning in Ontario and, with regards to GI, it outlines provincial interests such as protecting and managing natural resources. Note that municipalities are the approval authority for Planning Act applications.

Under the Planning Act, the Provincial Policy Statement (PPS) provides policy direction on matters of provincial interest related to land use planning and development. Municipal official plans are the vehicle for implementation of this PPS.

O. Reg. 588/17: Asset Management Planning for Municipal Infrastructure

This regulation, made under the Infrastructure for Jobs and Prosperity Act, is intended to improve how municipalities plan for their infrastructure. Current infrastructure progress within municipalities is used to help build consistency and standardization within asset management plans. This regulation also provides the means to apply best practices and collection of data.

As the function of GI relates to the collection, transmission, treatment, retention, infiltration, control, or disposal of stormwater, it is categorized as a stormwater management asset. Currently, Green Infrastructure is classified as a non-core asset and not a stormwater management asset.

O. Reg. 191/11: Integrated Accessibility Standards, The Accessibility for Ontarians with Disabilities Act, 2005

As part of the Accessibility for Ontarians with Disabilities Act (AODA), the Integrated Accessibility Standards regulation establishes the accessibility standards, compliance framework for obligated organizations, and introduces requirements for information and communications, employment and transportation.

O.Reg. 239/02: Minimum Maintenance Standards for Municipal Highways

This regulation sets out the minimum standards of repair/maintenance for highways under municipal jurisdiction. This provides an available statutory defence to a municipality in regards to the levels of care on roads and bridges.

Ontario Provincial Standard

The Ontario Provincial Standards for Roads and Public Works (OPS) is an organization that produces a set of standards used by road and public works owners, contractors and consultants in Ontario. These standards include the Ontario Provincial Standard Specifications (OPSSs) and Drawings (OPSDs) which are updated bi-annually.

Ministry of Environment, Conservation and Parks Stormwater Management Planning and Design Manual

This manual provides a baseline reference for technical and procedural guidance for planning, design and review of stormwater management practices.

Municipal Engineers Association - Class Environmental Assessment

This sets out standardized planning processes for classes or groups of activities. The document applies to projects that are routinely carried out which have predictable environmental impacts that are readily manageable.

Ontario Water Resources Act

The purpose of this act is to protect, conserve and manage Ontario's waters and to contribute to its sustainable use for long-term environmental, social and economic well-being.

GI in right-of-way that discharges stormwater runoff to receiving water bodies requires the same approvals as conventional stormwater management infrastructure.

Municipal Regulations

City of Toronto Official Plan

The purpose of the Official Plan is to ensure that the City of Toronto develops and improves to its full potential in areas such as transit, land use development, and the environment.

City of Toronto Green Streets Technical Guidelines

These guidelines provide the guidance, standards and selection tools for the planning, design, integration and maintenance of GI applications within the City of Toronto streetscape. The document presents City staff, developers, and consultants with objectives to meet sustainable stormwater planning and practice along with the appropriate selection of GI for retrofit/rehabilitation or new/reconstruction projects within an urban context.

City of Toronto Streetscape Manual

This manual provides guidance for design, construction and maintenance of sidewalk and boulevard improvements within the City of Toronto's road networks.

City of Toronto Complete Streets Technical Guidelines

The guideline provides a new approach and improvement toolbox for the design of City of Toronto streets by building on existing policies, guidelines, and recently successful street design and construction projects.

City of Toronto Salt Management Plan

This plan ensures that the City of Toronto follows appropriate practices and wise usages of de-icing road salt.

City of Toronto Tree Protection Policy (Tree By-Laws)

This policy was established to meet the City of Toronto goals for maintenance, growth, and enhancement of sustainable urban forests. This involves the regulation of injury and destruction of trees on both City and privately owned property to ensure the preservation and protection of trees within the City of Toronto. Specific By-Laws include Municipal Code Chapters 658, 813 and 608.

City of Toronto Specification for Construction Near Trees

Similar to the Tree Protection Policy, this specification is set out to ensure the preservation and protection of trees within the City of Toronto is integrated in the initial stages of construction planning for projects.

City of Toronto Wet Weather Flow Management Guidelines

These guidelines were set out to provide direction on the management of wet weather flow on a watershed basis in a way to recognize rainwater and snowmelt as resources. The objectives and principles established by the guidelines help to reduce the quantity and improve the quality of stormwater runoff.

City of Toronto Design Criteria for Sewers and Watermains

This design criteria provides consulting engineers and City of Toronto staff comprehensive guidance on the criteria necessary for the design of sewers and watermains.

City of Toronto Design Road Engineering Design Guidelines

These guidelines provide technical standards on street design and road works.

City of Toronto Utility Cut Permit Applications and Municipal Consent Requirements

The Municipal Consent Requirements (MCR) were established to provide an application review process for underground plant installments within City of Toronto streets. Requirements are set forth to ensure the City receives the necessary information and takes appropriate actions.

Toronto Green Standards, City Agency, Corporation and Division - Owned Facilities Version 3

This contains a consolidated standard for high performance City of Toronto building projects which applies to all non-residential developments planned and constructed by the City's Agencies, Corporations and Divisions.

City of Toronto Sewer Use By-laws

These By-laws were created with the intent to protect public safety, the environment, and City of Toronto infrastructure through establishing strict limits on the discharge allotment into sewer systems and natural watercourses.

Chapter 2 – Toronto's Physical Characteristics

Right-of-ways in Toronto are each home to their own unique set of physical characteristics. A full understanding of the characteristics of the area is required prior to selecting, designing, and implementing the appropriate GI system.

The following section should be read in conjunction with the maps provided in Appendix E, *City-wide Reference Maps* in the Green Streets Technical Guideline which can be found at: www.toronto.ca/services-payments/streets-parking-transportation/enhancing-our-streets-and-public-realm/green-streets/ as follows:

Map 1.0 – Topographical Gradients

Map 2.0 – Depth to Water Table

Map 3.0 – Depth to Bedrock

Map 4.0 – Soil Permeability

Map 5.0 – Natural Heritage System

Map 6.0 – Known Area of Soil Contamination

Map 7.0 – Subway, Streetcar and LRT Lines

Map 8.0 – Major Utility Corridors

Map 9.0 – Combined and Separated Sewers

Map 10.0 – Proximity to Flooding Areas

Map 11.0 – Stream Restoration Area

Map 12.0 – Flood Risk Area

Physical and Climatic Characteristics

The city of Toronto is located in Southern Ontario at latitude of 43.6532°N and longitude of 79.3832°W. Toronto is the capital city of the province of Ontario, and has a population of 2.93 million (StatsCan, 2017).

Toronto sits an average 76 m above sea level, has a total land area of 630 km^2, most of which is densely urban, with several ravines and large parks. Toronto is a waterfront city with 46 km of shoreline along Lake Ontario.

Toronto has a semi-continental climate, with a warm, humid summer and a cold winter. The average annual high temperature is 26°C and the average annual low temperature is -6.7°C (Environment and Climate Change Canada). According to the Design Criteria for Sewers and Watermains, frost penetration is considered to be 1.8 m in Toronto.

The maps included in Appendix E of the Green Streets Technical Guidelines can be referenced for a general understanding of the City's topography, depth to bedrock, depth to the water table, soil permeability, and known contamination. These maps—and accompanying text in Section 4.2.4 of the Green Streets Technical Guidelines—are to be referenced for a general understanding only. Site specific investigations are required to confirm that appropriate conditions are present for successful green infrastructure installation. They will also help determine various permutations of the system that might be required such as impermeable membrane liner and underdrain.

Toronto spans across Iroquois Sand Plain, South Slope and Peel Plain physiographic regions (Figure 2.6.1 from TRCA / CVC LID SWM 2010).

The Canadian Plant Hardiness Zone maps combine information about a variety of climatic conditions to determine plant hardiness and suitability across the country. The Toronto area spans the 6a and 7a plant hardiness zones as listed by the Government of Canada http://planthardiness.gc.ca/.

Microclimate can also affect local conditions and best practices suggest selecting only plants grown in the same, or colder Canadian Plant Hardiness Zone as the subject site. The optimal planting season for trees in Toronto, based on plant hardiness zones and frost-free days is as follows:

- Deciduous trees except those known to require spring only transplanting: March 1 - June 15 and September 1 – October 30
- Deciduous trees known to require spring only transplanting: March 1 - June 15
- Coniferous trees: transplant in early spring or late summer: early August to late October

Hydrology

Annual precipitation measured for Toronto has ranged from 592.7 mm to 1,049.6 mm over the past 25 years (Environmental & Climate Change Canada). The annual snowfall has ranged from 32.4 cm to 216.5 cm while the annual rainfall has ranged from 478.2 mm to 846.8 mm. The number of days of rainfall exceeding 25mm has ranged from 0-9 over the past 25 years.

The Toronto and Region Conservation Authority has several rain gauges throughout the City that can be utilized to collect more local weather data at the site of the GI project: http://beta.trcagauging.ca/

The City of Toronto's rain gauges can also be utilized to collect additional local weather data at the site of the GI project. Refer to Open Data source: https://open.toronto.ca/dataset/rain-gauge-locations-and-precipitation/ .

Chapter 3 – Green Infrastructure Planning and Siting

Green infrastructure systems should be strategically located to aid with stormwater management, urban tree canopy, traffic calming and making Toronto's streets green and complete. This section of the manual is intended to aid the user in selecting the most effective location for green infrastructure, both in new construction and in reconstruction projects. For the purpose of this manual, **new construction** is defined as new greenfield or brownfield development, and **reconstruction** is defined as projects with road realignment and resurfacing, projects with adjustments within the right-of-way that would enable installation of GI, or GI-focused projects where the intent is to specifically add GI to an existing streetscape, even if no other work is ongoing.

This section of the manual should be read in conjunction with the Green Streets Technical Guidelines selection tool. The Green Infrastructure Selection Tool can be found at www.toronto.ca/services-payments/streets-parking-transportation/enhancing-our-streets-and-public-realm/green-streets/ .

The tool provides users with a series of site conditions and constraints that can be used to filter out GI that aren't feasible at the project site.

Throughout the siting process, the following must be considered:

- Characteristics of the existing right-of-way conditions
- Impacts to existing, protected trees
- Characteristics and performance of the existing drainage system
- Potential extent of area to be managed by the GI
- Location specific water quality and quantity goals
- Integration within existing or planned streetscape

- Future maintenance requirements
- Minimization of lifecycle costs.

It is important to understand the two different mechanisms through which GI hydraulically interact with groundwater and existing stormwater management systems: 1) infiltration as shown in Figure 1, and 2) detention as shown in Figure 2.

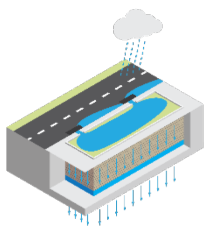

Figure 1: Infiltration System

Infiltration systems are designed to allow collected rainwater and runoff to return to the natural hydrological cycle by infiltrating into the subgrade. These systems will often have a mechanism to hydraulically connect the GI system to the City's stormwater sewer network, but rely on this connection solely to accommodate overflow conditions and not as an inline means of ordinary conveyance.

Figure 2: Detention / Slow-Release System

Detention systems, sometimes referred to as slow-release systems, are designed to collect rainwater and runoff and return it to the City stormwater sewer network albeit at a reduced flow rate and over an extended period to avoid coinciding with the peak stormwater flows experienced within the receiving network. Detention systems are a suitable alternative where infiltration systems are not achievable or appropriate. This will typically include areas with low soil permeability, high groundwater, contaminated soil, contaminated groundwater, and adjacency to basement or tunnel structures.

There are two guiding questions to ask when siting green infrastructure: 1) where *can* it go based on existing conditions, and 2) where *should* it go based on City needs? The parameters and investigations discussed in the subsequent sections will aid in determining the types of systems that can feasibly be installed at the site location, and also the goals and co-benefits that should be targeted through prescription of the GI system.

Green Infrastructure Siting Part 1 – Where Can it Go?

From the outset it is necessary to select the right type of GI system for the intended project area and to site it in the correct position. Physical and hydrologic conditions of a site will determine if GI is appropriate for your site, and if so, what features are required.

Prior to the site investigation phase, the maps noted in Chapter 2, *Toronto's Physical Characteristics* along with any detailed information from other projects in the area of the project, can provide the designer with the high-level information required to assess which GIs may be appropriate.

The *Green Infrastructure Selection Tool* provides users with a series of site conditions and constraints that can be used to filter out GI that aren't feasible at the project site.

Since GI systems are each site-specific, there is no universal method for all GI designs. However, the following factors should be primarily considered when selecting the GI features that suit your site:

- **Spatial requirements:** Ensure that there is sufficient available space to install the GI system while safely and efficiently maintaining all other right-of-way features and functions. For retrofit projects, the GI system should aim to replace or punctuate existing impervious surface.

- **Soil characteristics:** Existing soil permeability characteristics will influence whether GI can be feasibly designed as an infiltration system into permeable ground, or whether it must be designed as a detention system with underdrain due to poor infiltration properties of the underlying ground. Areas with known soil contamination require a detention system to prevent mobilizing contaminants. Soil investigation requirements are discussed in Table 1.

- **Topography:** Different GI systems function on different grades. Refer to Chapter 6, *Green Infrastructure System Design Criteria* for the allowable slopes for each GI system.

- **Groundwater Table:** Infiltration systems require a minimum clearance of 1.0m from the base of the GI's infiltration layer to the seasonal high groundwater table. This minimum clearance is to minimize risk of the GI system acting as a vector for groundwater contamination and to mitigate impacts of local groundwater mounding.

- **Proximity to utilities and underground features:** GI systems can coexist with underground utilities provided the right clearances, protections and approvals are achieved. Generally, utility crossings are permitted, but utilities running longitudinally through a system are not recommended. Additionally, GI proximity to basements or building foundations may prohibit infiltration-based systems. Membrane lined detention systems with positive connection to the municipal system may be required to avoid oversaturation if the required setback – typically 4m – from structures cannot be achieved. While longitudinal utilities are not preferred for siting, installation of continuous soil trenches over utilities is still feasible. Refer to Municipal Consent Requirements Appendix O, *Utility Vertical and Horizontal Clearance Guidelines* for required clearances to utilities: www.toronto.ca/services-payments/building-construction/infrastructure-city-construction/construction-standards-permits/standards-for-designing-and-constructing-city-infrastructure/?accordion=utility-cut-permit-applications-and-municipal-consent-requirements-mcr .

The following section describes field investigations that may be performed to obtain information about soil characteristics, topography, and groundwater. Space and underground features are further discussed in Chapter 4, *Design Considerations*.

The following information must be collected at the site before or during preliminary design to confirm the appropriate GI system(s) has been selected:

Geotechnical Assessment

Soil permeability is a key component to understanding which GI system is appropriate for a site. Additionally, soil type, compaction of existing subgrade materials, presence of contaminated materials, and depth to bedrock and water table must be understood in order to appropriately design the GI system.

Hydrologic Assessment

The analysis of hydrologic patterns at the site should be carried out in accordance with the City's Wet Weather Flow Management Criteria and Chapter 3, *Storm Sewers* in the Design Criteria for Sewers and Watermains manual. GI systems shall meet the targets specified in Chapter 4, *Design Consideration* to determine what level of runoff should be accommodated by the type of right-of-way.

Microclimatic Assessment

GI selection, in particular GI including plant life, will be informed by microclimatic conditions for which it is necessary to understand characteristics of the growing season at the project site including temperature, humidity, wind, precipitation, solar exposure and salt/brine exposure in snow piling areas.

Road, Boulevard Reconstruction or Modification

A new GI system, particularly for projects within an existing right-of-way, must integrate into the existing streetscape. A site assessment should be undertaken to observe:

- At grade and subsurface utilities
- Existing on-site and adjacent vegetation
- Existing boulevard widths and furniture including commercial / retail allowable frontages
- Nature of available sewerage system; storm or combined
- Land use—heavy industrial limits GI system placement due to likelihood of excessive sediment and pollutant loads.

A summary of field investigations is provided in Table 1.

Table 1: Summary of field investigations for GI siting

Assessment	Parameter	Location	Timing
Soil Properties	• Structure • Texture • Colour • Saturation condition (pre-dev) • Particle distribution • Bulk density • Nutrient content • Cation exchange capacity (CEC) • pH	At site location (if one site) OR At 50m maximum intervals along linear/corridor applications of GI	During or before preliminary design
Geotechnical Investigation (Boreholes / Monitoring Wells or Test Pits)	• Soil types • Soil layer depths • Soil contamination • Depth to bedrock • Depth of groundwater • Seasonally high water table • Groundwater chemical analysis • Hydraulic Conductivity	At site location (if one site) OR At 50m maximum intervals along linear/corridor applications of GI	During or before preliminary design

Assessment	Parameter	Location	Timing
Infiltration Testing	• Saturated hydraulic conductivity at elevation of GI system base • Go to Appendix C, *Site Evaluation and Soil Testing Protocol for Stormwater Infiltration* of the *Low Impact Development Stormwater Management Planning and Design Guide* for additional infiltration testing details: https://cvc.ca/low-impact-development/low-impact-development-support/stormwater-management-lid-guidance-documents/low-impact-development-stormwater-management-planning-and-design-guide/	At site location (if one site) OR At 50m maximum intervals along linear/corridor applications of GI	During or before preliminary design
Topographic Survey	• Surface flow paths and tributary catchment area	Across site and anticipated drainage area	During or before preliminary design
SUE Investigation	• Existing utilities • If new development, establish location of proposed new utilities in coordination with GI placement	Across entire site	During or before preliminary design
Site Walk	• Existing streetscape properties and boulevard/lane widths (for reconstruction projects) • Condition of existing drainage structures • Identify localized high and low points • Identify existing trees/drip lines/root zones	Across entire site	During or before preliminary design

The use of any existing record information is recommended prior to any field investigations to further understand parameters and to aid with initial siting.

Green Infrastructure Siting Part 2 – Where Should it Go?

The second factor to be considered is where should the GI be sited, and what kind of GI should be sited, based on the City's needs.

The City developed a "Green Streets Project Selection Process" in December of 2019 and updated in March 2021 which looked at the City's current State of Good Repair (SoGR) Program and highlighted where GI should be sited in the City based on various co-benefits. A co-benefit is an additional benefit that is achieved by the project when a green infrastructure system is installed. The selection process involves three phases:

- **GIS Analysis:** the program scores planned project areas based on GI co-benefits. The output is a series of maps which have been included in Appendix A, *Green Streets Project Selection Process*.

- **Desktop Analysis:** high priority project areas identified in the GIS Analysis stage proceed to a desktop analysis of suitability and feasibility. This includes factors discussed in Part 1 of this chapter, as well as identified in the Green Streets Technical Guidelines Maps.

- **Stakeholder Coordination:** the stage where infrastructure groups are consulted within the City to agree on which GI should be included as part of project scopes and associated available budgets.

How does this apply to this manual?

The maps produced as part of the development of the Green Streets Project Selection Process have highlighted where GI systems are most required for each of the following co-benefits of GI:

- stormwater management
- air quality
- tree canopy cover
- social wellness
- climate resilience

The maps attached in Appendix A, *Green Streets Project Selection Process* can be a useful tool in determining where GI is most beneficial, and also what type of GI should be considered based on the prioritized co-benefit, for example street trees should be prioritized for tree canopy cover, even if they may not always be the most effective system with stormwater management benefits.

Planning for New Construction

In order to meet the City's water quality and quantity objectives, Toronto Green Standard goals, urban tree canopy target, and improve the overall quality of streets in the City, GI should be considered for every new construction project within the City—whether it is public infrastructure or private developments.

Section 4 of the Green Streets Technical Guidelines – as well as the accompanying Green Streets Selection Tool, in MS Excel – provides information about a variety of street types, physical conditions, and existing utility scenarios where each GI system can be installed. This tool, in conjunction with the maps in Appendix A, *Green Streets Project Selection Process*, should be used as a preliminary assessment of what GI systems may be able to function in the proposed site, to be evaluated in detail against the criteria in Chapter 6, *Green Infrastructure System Design Criteria* of this manual.

Planning for Reconstruction and Retrofit Projects

In order to meet the City's water quality and quantity objectives, Toronto Green Standard goals, urban tree canopy target, and improve overall quality of streets in the City, GI should be considered for any capital projects where improvements are occurring within the streetscape, or as standalone retrofits in areas experiencing water quantity or quality issues, or lacking in urban tree canopy.

Section 4 of the Green Streets Technical Guidelines – as well as the accompanying Green Streets Selection Tool, in MS Excel – provides information about a variety of street types, physical conditions, and existing utility scenarios where each GI system can be installed in a retrofit or rehabilitation project—Tab 4.0 of the MS Excel tool. This tool, in conjunction with the maps in

Appendix A, *Green Streets Project Selection Process* should be used as a preliminary assessment of what GI systems may be able to be sited in an existing streetscape, to be evaluated in detail against the criteria in Chapter 6, *Green Infrastructure System Design Criteria* of this manual.

A major challenge in siting GI systems in existing streetscapes is coordination with the existing features such as utilities, clearway widths and street furniture which is discussed in Chapter 5, *Design Criteria for Common Elements*.

Chapter 4 – Design Considerations

The following section discusses general considerations that should be applied to all GI systems within the City's right-of-way and can help inform the designer when siting and designing the system.

Cold Weather Considerations

Cold weather can pose a challenge to the successful implementation and function of GI systems. However, with the proper design considerations, cold weather effects can be mitigated to ensure the proper function and durability of a GI system. Table 2 describes common challenges of designing / constructing GI systems in cold climates, and associated design considerations:

Table 2: Cold climate challenges and design criteria

Cold Climate Element	Challenge	Design Consideration
Cold Temperature and Frost Penetration	• Underdrain freezing • Surface freezing • Reduced biological activity • Reduced settling velocities • Frost heave • Reduced soil infiltration	• Minimum 200mm diameter underdrains • Include overflow with raised beehive catch basin inlet in vegetated GI systems • Planned overland flow route in case of frozen surface and blocked overflow • Ensure adequate road and right-of-way infrastructure foundation sub-drainage • Open-graded base/reservoir material • Design to favour draindown of GI system including reservoir material within 24 hours preferably, 48 hours maximum

Cold Climate Element	Challenge	Design Consideration
Short Growing Season	• Short time period to properly establish vegetation during construction	• Strict timing windows in specifications • Select cold-climate tolerant plant species
Snow Fall and Storage	• Higher runoff volumes during snowmelt • High pollutant loads during snowmelt • Snow storage on GI system causing compaction and plant damage • Potential for snow-clearing equipment to cause damage to GI • Pedestrian safety where presence of GI system may be less apparent with heavy snow accumulation in the ROW	• Prohibit snow storage in GI systems where snow is moved by mechanical equipment • Install winter season signage raised 1.2 m above ground or higher and/or consider snow poles at edges of GI systems • Provide raised curb and chamfered edges adjacent to mechanical snow removal routes

Cold Climate Element	Challenge	Design Consideration
Road Salt / Sand Application	• Pollutant load from salt and sand impacts vegetation and soil • Salt and sand application likely to clog GI systems	• Specify salt-tolerant plant species • Soil amendments to buffer salt loading • Size facility and position inlets to allow for precipitation and irrigation to routinely leach salt from soil in spring • Install pre-treatment where possible, such as a filter strip or catch-basin sump, to collect sand, grit and salt prior to entering the infiltration GI system • Locate GI to shelter plants from salt spray where possible through horizontal and vertical offsets • Timely and routine winter and springtime maintenance • Avoid siting GI near crosswalks and pedestrian gathering zones • Avoid placement of GI systems where salt applications are excessively high and educate property owners on salt-tolerance of GI systems • Consider adding “closable” inlets to block salt-concentrated runoff during winter months

**This table references the 2014 City of Edmonton Low Impact Development Best Management Practices Design Guide*

Urban Integration and Available Space

Toronto's right-of-ways are congested with above grade utility poles, street furniture, pedestrian clearway requirements, abutting building faces, underground infrastructure, utilities, and abutting basements. For new construction projects, GI systems should be part of the integrated streetscape design from the conceptual phase to allow for the required space to be allotted. For reconstruction or retrofit projects, siting must consider locations that a) have no impact on existing utilities/street furniture, b) may have utilities running perpendicular to the site with appropriate vertical clearance, or c) minor utility/street furniture relocation is required.

Municipal Consent Requirements

Municipal Consent Requirements, Appendix O, *Vertical and Horizontal Clearance Guidelines* can be found at: www.toronto.ca/services-payments/building-construction/infrastructure-city-construction/construction-standards-permits/standards-for-designing-and-constructing-city-infrastructure/?accordion=utility-cut-permit-applications-and-municipal-consent-requirements-mcr .

The clearances are established for utilities within the right-of-way, and these horizontal and vertical clearances will form the initial design requirements for GI systems to be spaced from existing or proposed features. Clearances less than those listed in Appendix O must be approved by the affected utility owner on a case-by-case basis.

For GI systems, the clearances to the utilities shall comply with the specified requirements in *Municipal Consent Requirements (MCR)* document. Exemptions to the specified utilities clearance requirements shall be discussed with the utility asset owners. The designer shall propose alternative considerations to meet the expectations of the City and impacted utility asset owners.

Considerations include a utility sleeve surrounding the crossing utility or inclusion of impermeable liners for GI systems where they cross over a utility in close proximity.

Where overhead utilities are present, all GI systems are possible, with consideration to tree species that remain shorter at full maturity or that have an accommodating branching pattern.

For the design of any GI in a new development, the design of new utilities should be done in coordination with the placement of green infrastructure such that sufficient space is allocated for GI systems, for example 30m^3 of below grade space for soil for trees and so on.

For major road reconstruction projects where GI is sited, utility location modifications should be considered to allow for sufficient space for GI.

Accessibility for Ontarians with Disabilities Act

The Accessibility for Ontarians with Disabilities Act (AODA) requires a minimum clearway of 1.5 m. A clearway means that the area must be kept free of sidewalk signs, patios, mailboxes, street furniture, and GI if installed within the boulevard. City requires a pedestrian clearway of 2.1 m. For new construction projects, this requirement should be integrated when placing GI systems and other streetscape requirements.

For retrofit projects, considerations for narrow GI systems such as green gutters, street trees with covered panels, GI systems that occur within the travelled roadway, for example bioretention curb extensions or GI systems that do not have a surface component such as permeable pavement and infiltration trenches, should be selected where boulevard widths are too small and/or inflexible with respect to the pedestrian clearway.

Building Set Backs

To avoid saturation of soil adjacent to building foundations and associated risks, infiltration-based GI systems shall be set back from buildings a minimum of 4 m unless impermeable liners are installed, or the building foundation has been waterproofed with liners or membranes and the proposed GI system has been agreed with the owner of the adjacent structure. Preference is to position the GI system such that building foundations or tunnels are not within a 1H:1V slope from the proposed infiltration layer.

Chapter 5 – Design Criteria for Common Elements

Vegetation and Planting

Design considerations for vegetation and planting will be referred to in design specifications and typical details.

Plant selections should be based on site conditions, microclimate, size of planting area and site proximity to Environmentally Sensitive Areas (ESAs) and ravines. The designer should consider planting of large growing shade trees wherever possible in green infrastructure systems. If trees are to be planted, the green infrastructure system should be graded accordingly with low points located on either side of root ball mounds as shown in standards T-850.051-1 to T-850.051-3, T.850.061-1, T-850.061-2, T-850.081-1, and T-850.081-2.

The T-850.025 series of standard details include planting details for trees, shrubs and herbaceous plants, as well as recommended plant lists and sample planting palettes for various site conditions and microclimates as follows:

- Planting lists and sample planting palettes for dry / sunny sites
- Planting lists and sample planting palettes for shady / moist sites
- Planting lists and sample planting palettes for urban sites including a tree species list for harsh, urban conditions provided in the following table
- Planting lists and sample planting palettes for suburban sites
- Planting lists and sample planting palettes for bioretention facilities.

Table 3 provides a list of the tolerant tree species for paved boulevards / hardscape environments.

Table 3: Tolerant tree species for paved boulevards and/or hardscape environments

Scientific Name	Common Name
Gleditsia Triacanthos	Honey Locust
Ulmus Americana	American Elm Cultivars
Gymnocladus Dioicus	Kentucky Coffee-tree
Celtis Occidentalis	Hackberry
Quercus Macrocarpa	Bur Oak
Ginkgo Biloba	Ginkgo / Maindenhair Tree*
Acer Rubrum x Saccharinum or Acer x Freemanii	Freeman Maple**
Acer Saccharinum	Silver Maple**
Tilia Cordata	Littleleaf Linden**
Tilia Americana ‘Redmond’	Redmond Linden**
(*) Species to be limited to retrofit applications where planting/growing spaces are limited. Rooted condition to be container grown tree or small wire basket. (**) Less tolerant of salt conditions. Plant only in raised planters/beds or on a flanking residential boulevard.	

Growing Media and Soil Amendment

Design considerations for growing media should be referred to in design specifications.

Specification TS 5.10 Growing Medium includes requirements for topsoil, coarse sand and compost components, soil amendments as well as applications for use in various planting conditions and GI practices as follows:

- Existing Site Soil: For seeding, sodding and tree planting, may be used as growing medium at sites where the existing soil has been analyzed by an agricultural soil scientist and determined to be suitable for its intended purpose. The City may approve the use of existing soils and may require additional amendments for the soil as recommended by the soil report.

- Type 1 – Standard Mix: For sodding and trees planted in turf, a mixture of topsoil, coarse sand and compost components mixed in the appropriate proportions, such that the growing medium shall meet the parameters outlined in TS 5.10.

- Type 2 – Planting Bed Mix: For horticultural beds of shrubs and perennials, a mixture of topsoil, coarse sand and compost mixed to the proportions, outlined in TS 5.10.

- Type 3 – Boulevard Mix: For trees planted in hardscaped boulevards, a mixture of topsoil, coarse sand and compost mixed to the proportions, outlined in TS 5.10.

- Type 4 – Bio Retention Mix: For bio retention and rain gardens requiring high infiltration or pre-treatment, outlined in TS 5.10.

Acceptable Tolerances for the Review of Soil Tests

In the event that one or more parameters of a soil test are above or below the specified ranges, the following are the acceptable range of deviation, to be used at the discretion of the Contract Administrator.

Table 4: Type 1 – Standard mix

Parameter	Specified Range	Acceptable Deviation (to be used at Contract Administrator's Discretion)
Total sand (0.05 – 2 mm)	50 – 75%	5%
Silt	20 – 40%	5%
Clay	5 – 20%	5%
Gravel (2 – 75 mm)	< 5%	5%
pH	6.0 – 7.8	8.0% (Maximum)
Phosphorous	10 – 60	*
Potassium	80 – 250	*
Calcium	< 5000	*
Magnesium	100 – 300	*
Soluble salt	< 1.5 mmhos/cm	*
Percent organic matter (dry weight)	4 – 6%	1.5%
Infiltration / Permeability / Hydraulic Conductivity	50 –75 mm/hr at 85% Proctor density	

**Due to adjustments in mix design and environmental factors there will likely be high variability in available nutrient. Where values deviate from typical ranges direction from the testing lab can be followed to balance subsequent to installation.*

Table 5: Type 2 – Planting bed mix

Parameter	Specified Range	Acceptable Deviation (to be used at Contract Administrator's Discretion)
pH	6.0 – 7.8	8.0% (Maximum)
Phosphorous	10 – 60	*
Potassium	80 – 250	*
Calcium	< 5000	*
Magnesium	100 – 300	*
Soluble salt	< 1.5 mmhos/cm	*
Percent organic matter (dry weight)	4 – 6%	1.5%
Infiltration / Permeability / Hydraulic Conductivity	50 –75 mm/hr at 85% Proctor density	

**Due to adjustments in mix design and environmental factors there will likely be high variability in available nutrient. Where values deviate from typical ranges direction from the testing lab can be followed to balance subsequent to installation.*

Table 6: Type 3 – Boulevard mix

Parameter	Specified Range	Acceptable Deviation (to be used at Contract Administrator's Discretion)
Medium to coarse sand (0.25 – 2 mm) plus gravel (2 – 5 mm)	> 45%	5%
Total combined silt and clay	18 – 40%	5%
Gravel (2 – 75 mm)	< 5%	5%
pH	6.0 – 7.8	8.0 (Maximum)
Phosphorous	10 – 60	*
Potassium	80 – 250	*
Calcium	< 5000	*
Magnesium	100 – 300	*
Soluble salt	< 1.5 mmhos/cm	*
Percent organic matter (dry weight)	2.5 – 5%	1% (should NOT be lower than 2%)
Infiltration / Permeability / Hydraulic Conductivity	50 –75 mm/hr at 85% Proctor density	

**Due to adjustments in mix design and environmental factors there will likely be high variability in available nutrient. Where values deviate from typical ranges direction from the testing lab can be followed to balance subsequent to installation.*

Table 7: Type 4 – Bioretention mix

Parameter	Specified Range	Acceptable Deviation (to be used at Contract Administrator's Discretion)
Total sand (0.05 – 2 mm)	75 – 90% Infiltration 65 – 75% Treatment	5%
Silt	7 – 22% Infiltration 13 – 30 Treatment	5%
Clay	3 – 15%	5%
Gravel (2 – 75 mm)	< 10%	5%
pH	6.0 – 8.0	
Phosphorous	10 – 40	*
Potassium	80 – 250	*

Parameter	Specified Range	Acceptable Deviation (to be used at Contract Administrator's Discretion)
Calcium	< 5000	*
Magnesium	100 – 300	*
Percent organic matter (dry weight)	3 – 10%	
Hydraulic conductivity, saturated, sample compacted to 75-85% maximum dry density.	0.0021 – 0.0083 cm/s (75-300 mm/h) Infiltration 6.9 x 10-4 – 0.0021 cm/s (25-75 mm/ h) Treatment	
Cation exchange capacity	> 10 meq/100 g	

**Based - Canadian Standards Association – W200-18 Nation Standard for Bio Retention. Due to adjustments in mix design and environmental factors there will likely be high variability in available nutrient. Where values deviate from typical ranges direction from the testing lab can be followed to balance subsequent to installation.*

Hydrologic Considerations

Green infrastructure systems are typically designed to reduce runoff from a contributing drainage area at-source, prior to the runoff entering the ultimate receiver. Green infrastructure systems in the right-of-way shall be an integrated part of a proposed or existing stormwater management system.

Siting GI systems in a dense, urban environment may be challenging and constrained due to the presence of existing at-grade and underground features and utilities. Specific hydrologic design will depend on the green infrastructure system(s) selected, as well as the properties of the site. The hydrologic design considerations outlined in the following subsections shall be referenced for proposed GI systems relevant to:

1. Capital improvement projects, where alterations to the existing right-of-way are proposed, and

2. Planning applications for large sites where new streets are proposed.

The effectiveness of each GI system to meet the water balance and water quality performance measures below shall be assessed on a project-by-project basis.

Water Balance Performance Targets

GI Systems within the Right-of-Way for Capital Projects

GI systems within the right-of-way for capital projects should be designed to achieve the following water balance performance target:

- Capture and control stormwater runoff to the maximum extent possible, from all contributing drainage areas.

GI Systems within the Right-of-Way for New Streets

GI systems within the right-of-way for new streets being submitted through the planning process should be designed to achieve the following water balance performance targets:

- Capture and control stormwater runoff to the maximum extent possible, from all contributing drainage areas.
- If the new right-of-way is unable to support a GI system, or the proposed GI system in the new right-of-way is unable to meet the water balance targets as set out in the City's *Wet Weather Flow Management Guideline (WWFMG),* then additional GI systems will be implemented within the proposed development area to compensate.

Water Quality Performance Targets

GI Systems within the Right-of-Way for Capital Projects

GI systems within the right-of-way for capital projects should be designed to achieve the following water quality performance targets:

- Capture and treat stormwater runoff to the maximum extent possible, from all contributing drainage areas.

GI Systems within the Right-of-Way for New Streets

GI systems within the right-of-way for new streets being submitted through the planning process should be designed to achieve the following water quality performance targets:

- Capture and treat stormwater runoff to the maximum extent possible, from all contributing drainage areas.
- If the new right-of-way is unable to support a GI system, or the proposed GI system is unable to meet the water quality targets as set out in the City's WWFMG, the WWFMG water quality targets must be met using other measures.

Drainage Area – Impervious/Pervious Ratio

The Contributing Drainage Area (CDA) is the physical area that the GI system services. When considering appropriate CDAs for GI systems, the ratio of impervious surface to pervious surface should be considered. A general ratio of 10:1 impervious to pervious should be used – CDAs are discussed for specific systems in Chapter 6, *Green Infrastructure System Design Criteria*.

In addition to the I/P ratio, the land use is important to consider. To protect groundwater from possible contamination, source areas where land uses or human activities have the potential to generate highly contaminated runoff, for example vehicle fuelling, servicing, demolition, outdoor storage and handling of hazardous materials, heavy industry and high sediment areas should be evaluated and appropriate pre-treatment should be designed. Pre-treatment is discussed in Chapter 6, *Green Infrastructure System Design Criteria* for each system.

Depth to Bedrock, Water Table and Infiltration

GI system failures, including ponding, flooding, or clogging may occur if installed too close to the bedrock layer, water table, or subsoils of high clay content, as infiltration may be prevented.

The designer must obtain site information including the depth to bedrock, depth to water table including seasonally high elevations, the location of any perched water tables, and the infiltration rate of the sub-soil. The following shall be generally required criteria for infiltration-based GI systems:

- bottom of GI system is > 1m from top of bedrock layer
- bottom of GI system is > 1m from water table
- native soil infiltration rate is > 15mm/hr
- soil is found to be free of contaminants.

Should a GI system be sited at a location where the above criteria are not met, the system will require an underdrain or impermeable membrane liner.

For additional information regarding infiltration testing, go to Appendix C, *Site Evaluation and Soil Testing Protocol for Stormwater Infiltration* which can be found at:

https://cvc.ca/low-impact-development/low-impact-development-support/stormwater-management-lid-guidance-documents/low-impact-development-stormwater-management-planning-and-design-guide/ .

This includes details on site evaluation, soil testing protocol for stormwater infiltration, and applicable safety correction factors.

Further detail for each system is described in Chapter 6, *Green Infrastructure System Design Criteria*.

Inlets, Outlets, Overflows and Underdrains

Inlets and Outlets

The number, type and geometry of inlets and outlets determines the stormwater major drainage inflow and outflow capacity of a GI system. The standard drawings T-850.101 to T-850.107 provide inlet and outlet options for stormwater to enter and exit a GI system. This includes:

- curb cut inlet
- curb cut inlet with sediment pad
- catch basin with underground inlet
- side inlet with trench drain (optional)
- trench drain inlet
- curb cut outlet

- trench drain outlet

The intent of the standard drawings is to provide designers with a series of functional inlet options that can be connected to the planned GI system. Alternate inlet and outlet arrangements may be developed by designers on a case by case basis to maximise the efficiency, maintainability and durability of the constructed detail, subject to agreement with the City. In time, the City will develop increased knowledge of the performance of specific GI system components and lessons learned may help to continuously improve design and construction details.

As a general rule, the combination of inlets and outlets should be designed to allow the GI system to fill up to its full design ponding depth. The inlet capacity should be determined by using the Modified Rational Method with coefficients as noted in the *Wet Weather Flow Management Guidelines*:

$$Q = CiA$$

Where:

Q = Peak Flow, m^3/s

C = Runoff Coefficient

i = Average Rainfall Intensity, mm/hr

A = Drainage Area, m^2

Grated inlets should include a clogging factor of 0.5. All grates shall be non-slip and non-bolted. See TS 857 for further details.

Curb openings should have a minimum width of 600mm at the base to allow for maintenance and a minimum slope of 10 percent across from street to GI system to aid with drainage into the GI system and to reduce risk of stormwater infiltrating into the pavement-curb interface.

All inlets into GI systems require an energy dissipation mechanism in the form of a sediment pad or rip-rap. The designer should select the energy dissipation mechanism with due consideration of durability, ease of maintenance, safety, aesthetics and site-specific conditions.

Inlet Design Calculations

Applicable design equations are based on the following parameters:

- contributing area to each inlet
- roadway design profile and gutter configuration
- GI storage volume
- curb cut inlet length

The following equations are applicable to size curb cut inlets placed on-grade along linear right-of-way infrastructure where gutter flow depths are maintained below the height of the roadway curb.

The length of the curb cut inlet required for total interception of gutter flow on a roadway with a uniform cross-slope is given by:

$$L_T = K_u\, Q^{0.42}\, S_L^{0.3} \left[\frac{1}{nS_x}\right]^{0.6}$$

where:

L_T = Curb cut length required to intercept all of the gutter stormwater flow, m

K_u = Unitless factor, 0.817

Q = Gutter flow, calculated using the Modified Rational Method, m^3/s

S_L = Roadway longitudinal slope, m/m

n = Manning's coefficient, refer to Table 1 for appropriate reference values

S_x = Roadway cross slope, m/m

Table 8: Manning's n for street and pavement gutters (FHWA, 2009)

Type of gutter or pavement	Manning's n
Concrete gutter, troweled finish	0.012
Asphalt Pavement: Smooth texture Rough texture	0.013 0.016
Concrete gutter-asphalt pavement: Smooth Rough	0.013 0.015
Concrete pavement: Float finish Broom finish	0.014 0.016
For gutters with small slope, where sediment may accumulate, increase above values of “n” by	0.002

If space constraints preclude the full length required for total interception, the appropriate length can be significantly reduced by increasing the roadway cross slope or the equivalent cross slope, S_e. The equivalent cross slope can be increased by use of a continuously depressed or locally depressed gutter section in front of the curb cut inlet, refer to Figure 2. The length required for total interception is then calculated replacing S_x with S_e.

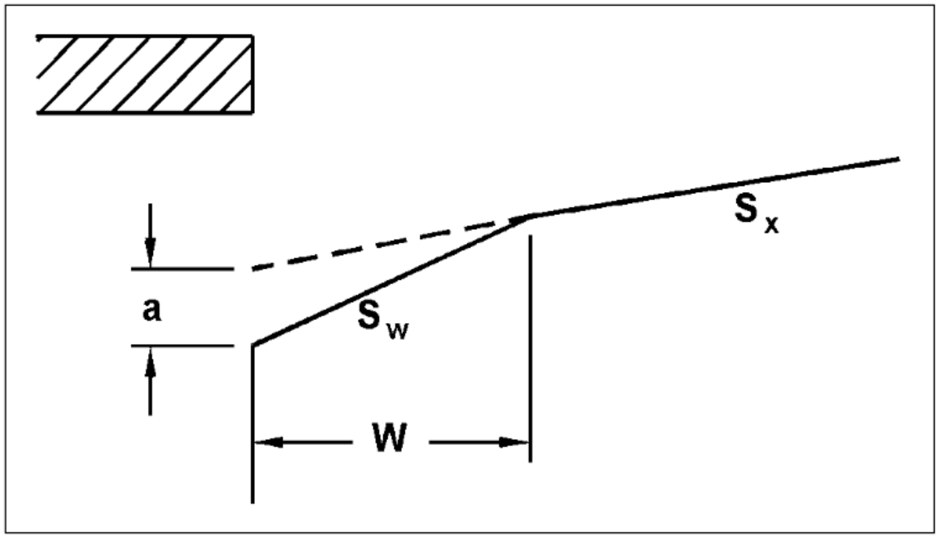

Figure 3: Depressed gutter section in front of curb opening inlet (FHWA, 2009)

S_e can be calculated using the following:

$$S_e = S_x + S'_w\, E_o$$

where:

S'_w = Cross slope of the gutter measured below the cross slope of the roadway, S_x

S'_w = $a/(1000W)$ or $S_w - S_x$, m/m

S_w = Cross slope of the depressed gutter section measured below the horizontal, m/m

W = Width of depressed gutter section, refer to Figure 2, m

a = Gutter depression, refer to Figure 2, mm

E_o = Ratio of flow in the depressed gutter section to the total gutter flow determined by the cross section upstream of the inlet

E_o can be calculated using the following:

$$E_o = \frac{1}{1 + \frac{S_w/S_x}{\left(1 + \frac{S_w/S_x}{\frac{T}{W} - 1}\right)^{2.67} - 1}}$$

where:

T = Total spread of water, m

T can be calculated using a modification of the Manning's equation to compute spread of flow in a triangular section. A modification is necessary as the hydraulic radius in the original equation does not describe the flow, especially when the spread may be more than 40 times the depth at the gutter. The modification involves integrating the Manning's equation for an increment of width across the section, neglecting the roughness along the curb edge since this resistance is negligible. The total spread of water in the triangular section can then be calculated using:

$$T = \left[\frac{(Qn)}{K_u S_x^{1.67} S_L^{0.5}}\right]^{0.375}$$

where:

K_u= Unitless factor, 0.376

If significant space constraints exist, precluding the use of even depressed gutter sections to fully capture the gutter flow, or if available space to place the GI system requires some of the treatment flow to be bypassed and treated further downstream, the efficiency of curb cut inlets shorter than the length required for total interception can be expressed with the following equation:

$$E = 1 - \left(1 - \frac{L}{L_T}\right)^{1.8}$$

where:

E = Curb cut inlet efficiency, Q_i/Q

Q_i = Reduced curb cut opening inlet capacity, m^3/s

L = Curb cut inlet length, m

It is important to note that any bypassed flow must be incorporated into the total gutter flow of the next downstream inlet, including the peak flow rate from its own contributing area.

A step-by-step procedure for sizing and spacing these inlets is as follows:

Step 1: Begin with a trial inlet spacing of between 25m to 100m and calculate the contributing area to each inlet. Include any off-site areas that drain to the roadway although, in general, large off-site contributing areas should be intercepted prior to discharge to the roadway.

Step 2: For each inlet location, calculate the peak flow rate from the contributing area.

Step 3: Based on the roadway geometry at each inlet, calculate the inlet length required for total capture of the gutter flow. Consider modifying the roadway cross slope or introducing a depressed gutter section to fully capture the flow.

Step 4: If space constrictions or a reduced total GI volume require an inlet length smaller than that required for total capture, calculate the captured flow and any bypass flow. Recalculate the peak flow rate to each downstream inlet to ensure that all the bypass flow is captured in the GI treatment train.

Step 5: Compare the volume of gutter flow captured with the available GI volume at each inlet. Reduce or increase the inlet spacing as required for an efficient design and resize the inlets beginning at Step 2 above.

Overflows

Overflow drains are designed to facilitate runoff beyond the GI system's design capacity entering the municipal stormwater system. The rim should be level with the maximum ponding depth of the GI system. The overflow mechanism included in T-850.091 is a vertical 450 mm diameter PVC chamber topped with a beehive grate. The size of the vertical barrel helps to keep the overflow clear in the winter while enabling easy access for inspection and maintenance. The domed shape of the beehive grate help keep the overflow free from debris blockage throughout the year.

Underdrains

When a system requires an underdrain, it shall be sized according to each system. The minimum requirements for an underdrain are 200 mm perforated HDPE or PVC piping. The pipe shall transition to non-perforated pipe a minimum of 1m into the GI system prior to connecting to adjacent City sewers to prevent migration of sediment material.

Where underdrains are specified, the designer must calculate the hydraulic performance of the GI system and ensure the necessary balance of overall inflow versus overall outflow meets the design objectives. If improperly designed, the GI system may drain down too quickly which could compromise water quantity management benefits, or the GI system could retain water for an excessive duration which could compromise capacity of the GI in subsequent storm events. Both of these situations could hinder plant growth. Where drain down is calculated to occur too rapidly relative to the design objectives, the designer may need to consider a flow control mechanism at the outlet of the underdrain.

Chapter 6 – Green Infrastructure System Design Criteria

The following chapter discusses GI system applications and design considerations for specific parameters for the following GI: stormwater tree trenches, bioretention, bioswale, enhanced grass swale, green gutter, filter strip, permeable pavement, and infiltration trench.

When reading the following sections, designers should ensure that the GI system includes elements that are required based on the nature of the selected siting location, but do not include additional engineered items – for instance, a redundant underdrain – to avoid higher capital costs, maintenance costs, and additional infrastructure in the right-of-way.

Continuous Soil and Stormwater Tree Trenches

A continuous soil trench (CST) is a structure designed and built to contain an adequate volume of continuous growing media to support tree growth to maturity under a paved boulevard.

Within constrained urban conditions, achieving individual volumes can be challenging and continuous trench design can be implemented to augment or connect to adjacent soil resources, thereby maximizing the inherent benefits, and minimizing cost. CSTs include both covered trenches with trees in pavement, and open planters that can either be raised or flush with surrounding pavements.

Within the right-of-way some of the tree planting areas are supported by additional infrastructure in order to purposefully manage stormwater runoff. Examples range from trench drain inlets, to growing medium mixes that promote drainage, to stormwater tree trenches. A CST that is purposefully designed and constructed to capture, infiltrate and filter stormwater runoff from a drainage area beyond the footprint of the trench is referred to as a Stormwater Tree Trench (STT).

All trees are considered GI and the priority when designing CST and STT should always be the establishment and growth of large growing shade trees to maturity.

Trench System Application

Properly designed, CST are appropriate for both new and retrofit conditions and should be located on streets that have sidewalks that are wide enough to accommodate the infrastructure related to the trenches, as well as maintaining an acceptable pedestrian clearway.

STTs can be used where stormwater can be conveyed into the soil volume and should typically be located close to the origin of the contributing stormwater runoff which may include parking lots, roadways, or alongside sidewalks. STTs may also be considered as bioretention facilities and certain design criteria specific to this aspect may be similar between both applications and/or be interchangeable. However, if the design criteria of a particular bioretention GI-practice precludes the growth of large, mature shade trees, then the health of the tree should take precedence, and a CST without a specific stormwater management function should be implemented.

A healthy tree canopy provides multiple, significant benefits to the public realm and depending on the site context and streetscape design, continuous soil trenches can be designed as open planters with seat walls or open/covered planting areas. The optimal condition for trees is always to provide the largest, open, that is to say uncovered planting area possible.

Because there is insufficient space at the surface on narrow and/or predominantly paved boulevards to accommodate large open planting spaces, many streets don't have street trees or they have street trees that require continual replacement because of the inhospitable growing conditions. CST and STT are examples of street design innovation because they are a means of accommodating the volume of uncompact growing medium necessary to support large growing shade trees to maturity.

Design Considerations

Several key design considerations should be incorporated into the planning, design, and construction of CST and STT:

- Width of sidewalk and pedestrian clearway within right-of-way

- Streetscape design including tree planting area (TPA) opening and tree spacing
- Soil volume requirements
- Soil trench dimensions and specific soil cell layout, if applicable. Refer to TS 853
- Urban and open space context
- Trees and vegetation selection
- Drainage, irrigation and aeration
- Utility location and coordination
- Constructability, operations and maintenance
- Adjacent land use and contributing drainage area (STT only)

Appropriate design parameters can be found in Table 9.

Table 9: Continuous soil trench with tree(s) and stormwater tree trench design considerations and site characteristics

Parameters	Design Considerations
Width of Sidewalk and Pedestrian Clearway Within Public Right-of-Way	Available sidewalk space within the public right-of-way should allow a minimum of 2.1 m unobstructed pedestrian clearway beyond continuous soil trench tree openings, curbs or tree fences.
Streetscape Design Including Tree Opening and Tree Spacing	Area of tree openings should be a minimum of 1.5 m^2 and tree openings within grates should be a minimum of 600 mm^2. Standard details include a hierarchy of design options for the surface treatment of tree planting spaces, with open, raised or tree fence options preferred to in-ground or grated tree openings. In narrow sidewalks with constrained public space, open planters with raised planter curbs or tree fences may not be suitable and flush tree grates may be the preferred design solution to achieve the required minimum pedestrian clearway. However, tree maintenance and growth must be factored into the design, and the eventual mature trunk flare and root collar size should be taken into consideration. Tree grates should be easily lift-able to facilitate tree planting and maintenance, and easily removable or expandable to accommodate trunk growth. Tree spacing should be 8 m on centre, but if necessary can be up to 10 m on centre. For new construction, tree spacing should be consistent and coordinated with site furnishings, street lighting, etc. In retrofit conditions, tree spacing should be determined based on the existing context, including street furnishings utilities, driveways and other elements. Urban Forestry must approve any proposed tree planting.
Soil Volume	Available space for continuous soil trenches should provide a minimum of 30 m^3 growing medium per tree, maximizing soil volume where possible.

Parameters	Design Considerations
	The minimum required soil volume can be achieved using a combination of open planters or covered trenches that can be supported by soil cells and structural slabs. In SoGR projects involving boulevard reconstruction, additional soil volume made be added under the sidewalk to support existing City trees. These can serve as "connector" trenches (or soil bridges), providing a means for street tree roots to access adjacent soil resources on private property. Refer to specification TS 5.10 Growing Medium.
Soil Trench Dimensions	The width of continuous soil trenches should be determined based on the available space within the public right-of-way. Continuous soil trenches and all components, including structural slabs, foundations and supports, soil cells, irrigation and drainage components, should be constructed within the public right-of-way. Where possible, allow tree roots to grow into adjacent native soil. For the purposes of Toronto Green Standard soil volume calculations, the depth of growing medium should be no less than 800 mm and no more than 1600 mm when measured from the surface of the sidewalk. In high groundwater conditions, a shallow trench with a minimum 600 mm depth of growing medium could be considered. Shallow soil trenches will require larger horizontal dimensions to achieve the minimum required soil volume. For continuous soil trenches, sides of trenches shall be engineered to have a stable angle of repose while providing the required soil volume. Avoid the use of geo-fabric or other solid material around the perimeter of trenches as this prevents lateral root growth. For continuous soil trenches with soil cells, refer to manufacturer’s site-specific soil cell layout including for soil trench dimensions, side slope, base and surface details.

Parameters	Design Considerations
	Refer to TS 850 for specifications for continuous soil trench with trees for new and retrofit installations and TS 853 for soil cell specifications.
Urban and Open Space Context	Continuous soil trenches on streets adjacent to public open space may utilize soil cells or structural slabs to create soil bridges into green spaces. Factors that may affect location and/or require design solutions for continuous soil trenches include locations with very narrow sidewalks, buildings with overhead canopies and where shallow utilities, low overhead wires, service or emergency access prevent a continuous soil volume.
Trees and Vegetation Selection	Designers should approach the selection of trees and vegetation based on suitability for site specific microclimate, including average temperatures, sun / shade, wind, groundwater levels and pollutants. Priority in selection of plant material should be the establishment and growth of large growing shade trees to maturity. If the site is not appropriate for a large growing shade tree, for exampledue to the presence of overhead wires and so on, a smaller tree should be planted. However, this determination, including species selection must be approved by Urban Forestry. Continuous soil trenches may not be appropriate for locations with minimal direct sunlight, high winds or downdrafts, and subject to excessive salt spray from adjacent roadways and bridges, although some hardy species may be tolerant of more difficult urban microclimates. Where soil cells are proposed on both private and public property, it is essential that a soil cell unit including any drainage or aeration piping not straddle the property line to enable future repairs as well as excavation on either side without impacting the adjacent property. Refer to TS 5.30 for planting specifications and to the T-850.025 series of standard details which include planting details for trees, shrubs and herbaceous plants, as well as recommended plant lists and sample planting palettes for various site conditions.

Parameters	Design Considerations
Drainage, Irrigation and Aeration	For in-ground Stormwater Tree Trenches (SST), seasonal high groundwater level shall be no less than one metre below the base of the facility. If the facility is planned in a high ground water condition, raised planter options should be considered. Note: This minimum one metre depth requirement applies only to SST – not CST. Where possible, surface runoff from sidewalks should be directed into soil trenches, that is to say CST and SST, to contribute to passive irrigation, however, where sidewalks are anticipated to be heavily salted, pre-treatment of water and ability to flush or irrigation and aeration pipes should be incorporated into the design. In all instances, a robust drainage and soil aeration system must be incorporated into the design. A 200 mm perforated underdrain, with a connection to storm sewer catch basin is recommended for all soil trenches.
Utility Coordination	Designers should approach utility owners during the preliminary design stage regarding allowable horizontal and vertical offsets between soil trenches including soil cells, root balls and other soil trench components and crossing utilities. The American Society of Civil Engineers Standard 38-02 defines the various quality levels of utility information. It is critical to determine the appropriate level necessary to adequately inform the design process. Designers and project manager should insist that SUE information include lateral utility connections. Utilities may be allowed crossing through the facility, provided suitable protection measures are implemented and allowable cover is maintained. Conflicts with crossing water/sewer laterals (commercial/residential connections) may be unavoidable. Construction phasing should be implemented to avoid interruptions to utility service. The clearances to the utilities shall comply with the specified requirements in *Municipal Consent Requirements (MCR)* document. Exemptions to the specified utilities clearance requirements shall be discussed with the utility asset owners. The designer shall propose alternative

Parameters	Design Considerations
	considerations to meet the expectations of the City and impacted utility asset owners.
Constructability	Designers should establish a standard tree spacing and tree opening size for new construction to allow for modular construction and stocking of components including modular pavements systems, tree rings and grates, irrigation and other components. For new and retrofit installations, the design of CST/SST must include measures to prevent the compaction of growing medium during construction. For retrofit projects, consider during the design process that access to buildings, as well as a minimum 1.5 m pedestrian clearway must be maintained during construction.
Operations and Maintenance	Designers should select durable, robust materials and finishes for all components of the continuous soil trenches and the design of open planters should facilitate maintenance and operations. Where possible, designers should use standard designs, parts and materials provide instructions, manufacturer guidelines, O&M manuals and so on as part of the design process. Refer to the *Lifecycle Activities for Green Infrastructure in the Right-of-Way* manual for further information.
Site Topography (STT only)	STTs are best installed in areas where contributing slopes are between 1 to 5%, but not greater than 20%.
Native Soil (STT only)	STTs can be installed over any type of soil, but are recommended to be installed over hydrologic soil groups A and B to best achieve water balance targets.
	STTs should typically be installed where native soil infiltration rates are greater than 15 mm/hr (hydraulic conductivity greater than 1×10^{-6} cm/s). An underdrain will be required for soil infiltration rates less than 15 mm/hr.
Building Setback (STT only)	STTs should be setback from abutting building foundations a minimum of 4 m unless otherwise specified by local or provincial building codes. The use of an impermeable liner or trench dam, for example hard packed clay material or flowable fill, extending the full height of the facility may allow placement within the setback requirement subject to obtaining necessary approvals.

Parameters	Design Considerations
Contributing Drainage Area (STT only)	Typical contributing drainage area should be 100 m^2 to 0.5 ha with a maximum recommended value of 0.8 ha.
Geometry (STT only)	STTs have similar geometries to bioretention facilities detailed in the following section but should also accommodate adequate soil volumes for trees. Typical ratios of impervious drainage areas to STT footprint surface area range from 5:1 to 15:1.
	Low points on the filter bed should be centrally located where no trees are planted and positioned on either side of the root ball mound.
Pre-treatment (STT only)	Pre-treatment varies based on site context, but the use of sediment pads with curb cut inlets as per T-850.102, catch basins with underground inlet as per T-850.104, and trench drain inlets with cleanouts as per T-850.107 should be most frequently adapted for urban contexts. Other pre-treatment options include filter strips and rip-rap.
Filter Media (STT only)	STTs should compose of a bioretention filter media as specified in TS 5.10 Growing Medium, with a minimum depth of 1.2 m to accommodate tree planting.
Drainage Layers (STT only)	The drainage layer should be a minimum depth of 450 mm and filled with 20 to 50 mm diameter, uniformly graded, clean washed angular stone.
	A 100 mm deep choker layer composed of 20 to 10 mm clean washed HL 6 aggregate shall be placed above the drainage layer to separate the overlaying filter media.
Geotextile Liners (STT only)	The geotextile should be a non-woven needle punched, or woven monofilament geotextile fabric. Woven slit film and non-woven heat bonded fabrics should be avoided as they are susceptible to clogging.
	A geotextile liner should be specified only along the sides of the drainage layers to prevent clogging of the aggregate voids, soil slumping, and downward or lateral migration of finer soil particles. If placed incorrectly or around the perimeter of the entire GI facility, it will prevent lateral root growth and as such, is incompatible with growing trees to maturity.
Underdrain (Optional for STT only)	If required, the underdrain should be a 200 mm diameter HDPE or equivalent material perforated pipe located a minimum of 150 mm from the bottom of the storage layer. A minimum elevation difference of 1 to 1.5 m between the inflow point and the invert of the downstream storm drain connection is preferred to provide sufficient head.

Parameters	Design Considerations
Overflow Outlet Structure (STT only)	A beehive catch basin as per drawing T-850.091 should be sized and placed in the STT facility to safely convey large storm events to the storm sewer. The overflow invert shall be set from 150 mm to a maximum of 600 mm above the filter bed surface.
Water Quality (STT only)	An estimate of achievable pollution removal percentages by STT and similar bioretention facilities include upwards to 80% of Total Suspended Solids (TSS), 80% of total heavy metals (e.g. lead, copper, zinc), and 45 to 70% of Total Phosphorus (TP). These parameter values are greatly influenced by filter bed properties and depth, underdrain, pre-treatment, number of bioretention cells and vegetation cover.
Water Balance (STT only)	Estimated runoff reductions are 85% without underdrains and 45% with an underdrain. These parameter values are greatly influenced by native soil infiltration rates, rainfall patterns, GI sizing, and other environmental factors due to varying site contexts.
Drain-down Time (STT only)	Bioretention cells are preferred to be drained in <48hrs; but depending on native soil and underdrain application, time to drain shall be no longer than 96hrs for partial infiltration with a maximum ponding depth less than 300mm. Maximum surface ponding duration is preferred to be <24hrs to limit mosquito breeding; however, no longer than 48hrs. For filter media depths less than 1 m, a maximum surface ponding of 85 to 100 mm is acceptable.
Velocities (STT only)	Less than 0.3 m/s in planted areas; less than 0.9 m/s in mulched zones. Erosion control measures shall be installed at point-source inlets to prevent scour during the 100-yr design storm. Discharge rates should follow maximum overflow or underdrain flow rates in design events (2-yr, 5-yr, 10-yr, 25-yr, and 100-yr).

Bioretention

Bioretention facilities are structural stormwater controls effective at improving stormwater runoff quality and reducing total stormwater runoff using a combination of soil filter media and vegetation to filter, treat, temporarily retain, and infiltrate stormwater runoff. A bioretention facility typically consists of adequate pre-treatment, an inlet, a planting bed, a granular filter/storage reservoir, an underdrain, and appropriate outlet/overflow structures. Performance research has indicated bioretention systems to be one of the most effective GI for pollutant removal. Bioretention systems included in the City's GI standard drawing set are defined in the Green Streets Technical Guidelines as follows:

- **Bioretention Planters:** Bioretention planters are constructed with near-vertical walls, are often narrow and rectangular in shape and can be installed in close proximity to utilities, driveways, trees, light standards and other street features. Bioretention planters receive roadway runoff through curb inlets and by overland flows from the surrounding sidewalk and paved surfaces.

- **Bioretention Curb Extensions:** Curb extensions and bump-outs provide another design variation for the bioretention practice. They can be located at intersections, mid-block areas, and at transit stops within the Edge and Roadway Zones of various street types. In addition to stormwater management functions, curb extensions / bump-outs can also enhance biodiversity, offer visual appeal and provide traffic calming benefits. Curb extensions / bump-outs are ideal for street retrofit projects as they can usually be installed within the limits of existing street cross-sections. Figure 4 illustrates the cross-section of a bioretention curb extension and its typical components.

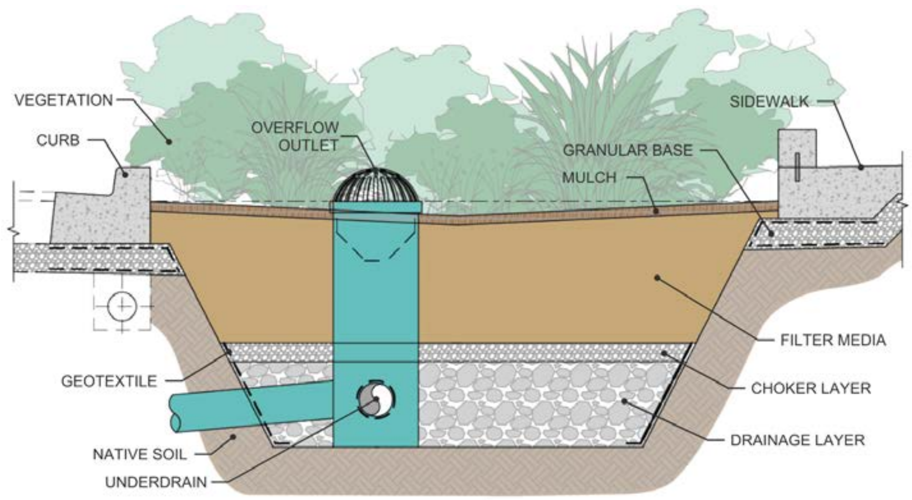

Figure 4: Bioretention curb extension cross-section

- **Bioretention Cells:** Bioretention cells provide a design variation that is suitable for more suburban street types within Furnishing / Planting Zones or Medians where space is not as constrained. This form of bioretention often receives overland flows from the surrounding landscape and from the roadway through curb cut inlets.

- **Rain Gardens:** Rain gardens are sunken planting beds constructed of highly permeable nutrient rich soils. They can include an engineered soil layer and overflow structure to increase their stormwater management performance. Rain gardens should always be designed to drain efficiently after a storm event to avoid creating areas of standing water where mosquitoes can breed. They are well-suited to suburban neighborhood street types and can be installed within Planting Zones, Medians, and Islands.

Green Infrastructure System Application

Bioretention facilities can be used where stormwater can be conveyed to a landscaped area. They should typically be located close to the origin of the contributing stormwater runoff which includes parking lots, within traffic islands, abutting roadways, or alongside sidewalks. They should be used as source control devices, rather than end-of-line devices. Unless precluded by the specifics of a constrained site, an appropriately vegetated filter strip should be provided upstream of the bioretention inlet for adequate pre-treatment. In spatially constrained conditions, a structural pre-treatment device such as a sediment pad or pre-treatment sump may be adopted. Placement of a bioretention facility should consider impacts of vegetation growth and any sightlines required around traffic intersections and/or driveways. Locating a bioretention facility should also consider future conflicts between any overhead wires and the future canopy of planted trees. Depending on native soil conditions and other physical constraints, a bioretention system may be designed for full infiltration or for partial infiltration with the use of an underdrain.

Properly designed, bioretention facilities are appropriate for both new and retrofit conditions. Forms of bioretention systems include rain gardens which collect runoff from low to medium residential developments, hard-edged stormwater planters for ultra-urban developments adjacent to buildings or in plazas, and as extended tree pits and/or curb extensions located within the roadway right-of-way.

Salt-resistant plants and soils are also required to improve the longevity of the system and optimize maintenance requirements. Other benefits of bioretention systems include the reduction in thermal aquatic impacts and the urban heat island effect due to the introduction/expansion of soils and vegetation within urban areas.

Infiltrating bioretention facilities should not be located close to abutting building foundations or within the two-year time-of-travel of wellhead protection areas. Bioretention facilities should not be located in areas where surrounding topography exceeds 20% slopes. Bioretention facilities should also not be placed where the removal of protected trees would be required.

Design Considerations

Several key design considerations should be incorporated into the planning, design, and construction of bioretention facilities as follows:

- Contributing drainage area
- Surrounding topography
- Soil infiltration rates
- Geometry
- Filter media properties

- Utility coordination
- Location and size of existing protected trees
- Required pollutant removal rates (e.g. TSS removal rate)
- Depth to seasonal high groundwater level
- Total maximum volume of snow, ice, and water during snow melt periods
- Prioritizing large growing shade trees and tree planting in bioretention facilities if the site has sufficient space be available for soil volume

Appropriate design parameters can be found in Table 10. Typical details of bioretention facilities can be referred to in the T-850.051 series, T-850.061 series, T-850.071, T-850.072, and T-850.081 series.

Table 10: Bioretention design considerations and site characteristics

Parameters	Design Considerations
Site Topography	Bioretention facilities are best installed in areas where contributing slopes are 1 to 5%, but not greater than 20%.
Native Soil	Bioretention facilities can be installed over any type of soil, but are recommended to be installed over hydrologic soil groups A and B to best achieve water balance targets. Hydrologic soil group classification is based on the ability of the soil to transmit water, with Group A being most permeable and Group D being least permeable. Group A soils are sand, loamy sand or sandy loam types; Group B soils are silt loam or loam types; Group C soils are sandy clay loam types; and, Group D soils are clay loam, silty clay loam, sandy clay, silty clay or clay types.
	Bioretention facilities should typically be installed where native soil infiltration rates are greater than 15 mm/hr (hydraulic conductivity greater than $1x10^{-6}$cm/s). An underdrain will be required for soil infiltration rates less than 15 mm/hr.
Groundwater Buffer	The base of the facility should be a minimum of 1m above the seasonal high groundwater level to prevent groundwater contamination.
Building Setback	Bioretention facilities should be setback from abutting building foundations a minimum of 4m unless otherwise specified by local or provincial building codes. The use of an impermeable liner or trench dam (e.g. hard packed clay material or flowable fill) extending the full height of the bioretention facility may allow placement within the setback requirement subject to obtaining necessary approvals however this will preclude the inclusion of a large-growing shade tree within the facility

Parameters	Design Considerations
Utility Coordination	For all utility coordination, it is important to ensure complete and accurate Subsurface Utility Engineering (SUE) information is available for review during design considerations. Designers should approach utility owners during preliminary design regarding allowable horizontal and vertical clearances between the bioretention facility and crossing utilities. Utilities may be allowed to cross through the facility provided suitable protection measures are implemented and allowable cover is maintained. Conflicts with crossing water/sewer laterals (commercial/residential connections) may be unavoidable. The clearances to the utilities shall comply with the specified requirements in *Municipal Consent Requirements (MCR)* document. Exemptions to the specified utilities clearance requirements shall be discussed with the utility asset owners. The designer shall propose alternative considerations to meet the expectations of the City and impacted utility asset owners. Construction phasing should be implemented to avoid interruptions to utility service. Potential interference between overhead phone/hydro wires and the typical mature tree canopy height should be confirmed.
Contributing Drainage Area	Typical contributing drainage area should be 100 m^2 to 0.5 ha with a maximum recommended value of 0.8 ha.
Geometry	Available space for the bioretention facility, which includes both permeable and impermeable areas, should be reserved at 10-20% of the contributing drainage area. The bottom of the facility shall be flat to encourage infiltration across the full footprint area. A multi-cell design can be used where a flat surface cannot be maintained along the length of a bioretention facility installed along a sloped roadway.
	A flat bottom with a length/width ratio of 2:1 is recommended. 4:1 (H:V) side slopes are preferred, but hard vertical edges may be used in retrofit or constrained configurations. The maximum side slope should be 3:1.
	Typical ratios of impervious drainage areas to bioretention footprint surface area range from 5:1 to 15:1.
	Low points on the filter bed should be centrally located where no trees are planted and positioned on either side of the root ball mound shown in details T-850.051-1 to T-850.051-3, T.850.061-1, T-850.061-2, T-850.081-1, and T-850.081-2
Pre-treatment	Pre-treatment varies based on site context, but the use of sediment pads with curb cut inlets as per T-850.102, catch basins with underground inlet as per T-850.104, and side inlet with trench drain

Parameters	Design Considerations
	as per T-850.106 should be most frequently adapted for urban contexts. Other pre-treatment options include filter strips and rip-rap.
Filter Media, Planting Soil and Vegetation / Trees	For material specifications for filter media, planting soil, and vegetation, see Chapter 5, Design Criteria for Common Elements.
	A typical depth of filter media ranges from 1 to 1.25 m, but given constrained applications, may be a minimum of 0.6 m (minimum 1.2 m for bioretention with trees) to ensure water quality benefits are achieved.
	For tree planting, refer to Table 9.
Drainage Layers	The drainage layer should be a minimum depth of 450 mm and filled with 20 to 50 mm diameter, uniformly graded, clean washed angular stone.
	A 100 mm deep choker layer composed of 20 to 10 mm clean washed HL 6 aggregate shall be placed above the drainage layer to separate the overlaying filter media.
Geotextile and Geomembrane Liners	The geotextile should be a non-woven needle punched, or woven monofilament geotextile fabric. Woven slit film and non-woven heat bonded fabrics should be avoided as they are susceptible to clogging.
	A geotextile liner should be specified only along the sides of the bioretention drainage layers to prevent clogging of the aggregate voids, soil slumping, and downward or lateral migration of finer soil particles. If placed incorrectly or around the perimeter of the entire GI facility, it will prevent lateral root growth and as such, is incompatible with growing trees to maturity. Horizontal applications of geotextile should also be avoided within the drainage layers due to fabric clogging and greater susceptibility to system failure.
	The use of an impermeable geomembrane liner may be specified if the runoff contains higher pollutant loading concentrations (e.g. in vehicle refueling areas, servicing and demolition areas, outdoor storage and handling areas for hazardous materials and some heavy industry sites), or if the bioretention cell is in proximity to structural foundations to limit lateral flow underneath abutting roadways, parking lots, or sidewalks.
Underdrain (Optional)	If required, underdrain should be a 200 mm diameter HDPE or equivalent material perforated pipe located a minimum of 150 mm from the bottom of the storage layer. A minimum elevation difference of 1 to 1.5 m between the inflow point and the invert of the downstream storm drain connection is preferred to provide sufficient head.

Parameters	Design Considerations
Overflow Outlet Structure	A beehive catch basin as per drawing T-850.091 should be sized and placed in the bioretention facility to safely convey large storm events to the storm sewer. The overflow invert shall be set from 150 mm to a maximum of 600 mm above the filter bed surface.
Water Quality	An estimate of achievable pollution removal percentages by bioretention facilities include upwards to 80% of Total Suspended Solids (TSS), 80% of total heavy metals (e.g. lead, copper, zinc), and 45 to 70% of Total Phosphorus (TP). These parameter values are greatly influenced by filter bed properties and depth, underdrain, pre-treatment, number of bioretention cells and vegetation cover.
Water Balance	Estimated runoff reductions are 85% without underdrains and 45% with an underdrain. These parameter values are greatly influenced by native soil infiltration rates, rainfall patterns, GI sizing, and other environmental factors due to varying site contexts.
Drain-down Time	Bioretention cell are preferred to be drained in <48hrs; but depending on native soil and underdrain application, time to drain shall be no longer than 96hrs for partial infiltration with a maximum ponding depth less than 300mm. Maximum surface ponding duration is preferred to be <24hrs to limit mosquito breeding; however, no longer than 48hrs. For filter media depths less than 1m, a maximum surface ponding of 85 to 100 mm is acceptable.
Velocities	Less than 0.3 m/s in planted areas; less than 0.9 m/s in mulched zones. Erosion control measures shall be installed at point-source inlets to prevent scour during the 100-yr design storm. Discharge rates should follow maximum overflow or underdrain flow rates in design events (2-yr, 5-yr, 10-yr, 25-yr, and 100-yr)

Bioswales

Bioswales, sometimes referred to as infiltration swales or dry swales, are linear vegetated open channels designed to convey, treat, and infiltrate stormwater runoff. Bioswales are often used in conjunction with check dams to increase hydraulic residence times and reduce conveying velocities, thus improving filtration and infiltration capacity. When designed with adequate pre-treatment, bioswales provide water quality improvements through TSS removal similar to bioretention systems. Figure 5 and Figure 6 illustrates the cross-section of a bioswale system and its typical components in a softscape and hardscape context, respectively.

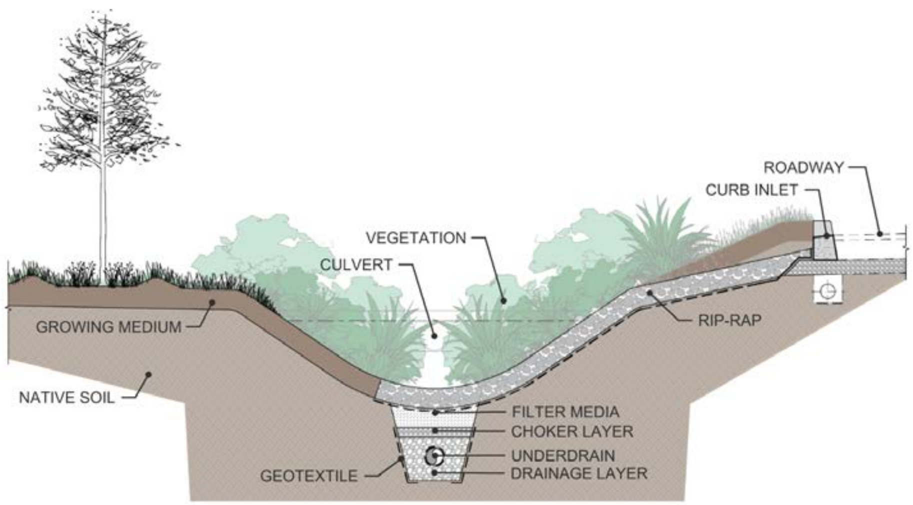

Figure 5: Bioswale cross-section in softscape

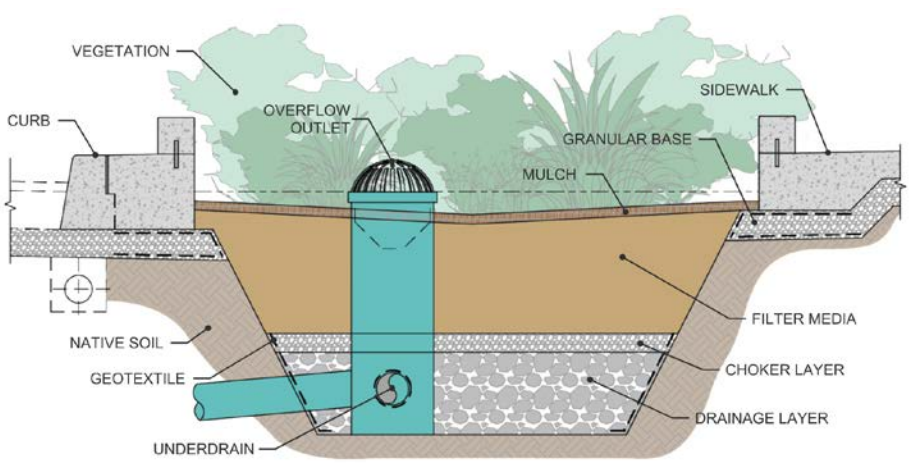

Figure 6: Bioswale cross-section in hardscape

Green Infrastructure System Application

Bioswales are often installed along linear roadway infrastructure, but can also be used to convey stormwater from general site areas when available space and site topography permit their proper design. However, due to the generally large area required, bioswales are typically impractical for retrofit conditions or dense, urban environments unless an existing drainage ditch may be properly repurposed. Some examples of applications include managing runoff from parking lots, roofs, and pervious surfaces, such as landscaped areas, parks, and residential lots.

Bioswales are appropriate as snow storage locations, but should be sized appropriately to prevent the inundation of abutting sidewalks, or roadways or both during the winter months and spring snowmelt. Using salt-tolerant plants and soils is necessary to improve the longevity of the system and optimize maintenance requirements. The types of vegetation used significantly alters the appearance of bioswales and should be selected to enhance its aesthetic value and accommodate the planting palettes of surrounding areas.

Bioswales are typically used for aesthetic purposes, general conveyance, or water quality improvement purposes. They are generally not well suited to meet peak flow rate requirements unless adequate outlet control is provided, and native soils allow for significant infiltration.

Design Considerations

Several key design considerations should be incorporated into the planning, design, and construction of bioswale facilities:

- Contributing drainage area
- Surrounding topography
- Soil infiltration rates
- Geometry
- Filter media properties
- Permissible velocities
- Utility coordination
- Required pollutant removal rates (e.g. TSS removal rate)
- Depth to seasonal high groundwater level

- Total maximum volume of snow, ice, and water during snow melt periods

Appropriate design parameters can be found in Table 11. Typical details of bioswales can be referred to in drawings T-850.111 and T-850.112.

Table 11: Bioswale design considerations and site characteristics

Parameters	Design Considerations
Site Topography	Bioswales are best installed in areas where contributing slopes are between 0.5 to 4.0%, and no greater than 6.0%. Check dams are recommended where slopes exceed 3.0%.
Native Soil	Bioswales can be installed over any type of soil but are recommended to be installed over hydrologic soil groups A and B to best achieve water balance targets. Refer to Table 10 for hydrologic soil group definitions.
	Bioswales should typically be installed where native soil infiltration rates are greater than 15 mm/hr (hydraulic conductivity greater than 1×10^{-6}cm/s). An underdrain will be required for soil infiltration rates less than 15 mm/hr. Additionally, infiltration rates may be increased by tilling native soil to a depth of 300 mm below the bottom of the facility. Refer to TS 5.10 for more information regarding growing medium and tilling. Amending with compost to reach a total organic content percentage of 8 to 15% by weight or 30 to 40% by volume is recommended.
Groundwater Buffer	The base of the facility should be a minimum of 1m above the seasonal high groundwater level to prevent groundwater contamination.
Bedrock Buffer	Similar to groundwater buffer requirements, bedrock or other impermeable layers shall be no less than 1m below the base of the facility.
Building Setback	Bioswale facilities should be setback from abutting building foundations a minimum of 4 m unless otherwise specified by local or provincial building codes. The use of an impermeable liner and underdrain system may allow placement within the setback requirement subject to obtaining necessary approvals.
Utility Coordination	For all utility coordination, it is important to ensure complete and accurate Subsurface Utility Engineering (SUE) information is available for review during design considerations. Designers should approach utility owners during preliminary design regarding allowable horizontal and vertical clearances between the bioswale and crossing utilities. Utilities should not be laid parallel to the

Parameters	Design Considerations
	bioswale centerline. Utilities may cross bioswales given adequate special protection measures (e.g. double-casing). The clearances to the utilities shall comply with the specified requirements in *Municipal Consent Requirements (MCR)* document. Exemptions to the specified utilities clearance requirements shall be discussed with the utility asset owners. The designer shall propose alternative considerations to meet the expectations of the City and impacted utility asset owners.
Contributing Drainage Area	Bioswales are capable of handling a varied range of contributing areas from a conveyance capacity, if properly designed. However, once contributing areas exceed 2 ha, erosive velocities are commonly encountered and may prove challenging to mitigate.
	Typical impervious drainage area to bioswale area ratios are between 5:1 and 15:1.
Geometry	Bioswales are generally designed as trapezoidal or parabolic cross-sections. Side slopes of 4:1 (H:V) are preferred but should be kept at 3:1 at a maximum. In hardscape, geometries are similar to bioretention facilities and can make use of raised curb structures.
	The bottom width of the cross section should be between 0.75 m and 3m. A total width of at least 2 m is recommended.
	Longitudinal slopes between 0.5 to 4.0% are allowed provided that check dams are specified to reduce the effective slope when the longitudinal slope exceeds 3.0%.
	When used to treat and/or convey roadway runoff, the bioswale shall meander with the roadway providing a bioswale length equal to or greater than the adjacent roadway length.
	The length of the bioswale between culverts underneath crossing driveways should be 5m minimum.
	The total surface area of the bioswale should generally be 5 to 15% of their total contributing area or 10 to 20% of their total contributing impervious area.
	Bioswales should be of sufficient size to account for combined volumes of snow, ice and melt water during the spring without relying on infiltration.
Pre-treatment	Pre-treatment varies based on site context, but options include enhanced grass swales, filter strips, rip-rap, dense vegetation and sediment pads. Bioswales in hardscape may also consider side inlets with trench drains as per drawing T-850.106. If rip-rap is used in softscape applications, geomembrane liners are to be placed under the rip-rap extending 600mm from the inlet while geotextile fabric shall be placed under the remaining rip-rap as per T-850.111.

Parameters	Design Considerations
Filter Media, Planting Soil and Vegetation	Refer to the Common GI Elements section for material specifications for filter media, planting soil, and vegetation.
	A typical depth of filter media ranges from 1 to 1.25 m but given constrained applications, may be a minimum of 0.6 m (minimum 1.2 m with tree application) to ensure water quality benefits are achieved.
Drainage Layers	The drainage layer should be a minimum depth of 450mm and filled with 20 to 50 mm diameter, uniformly graded, clean washed angular stone.
	A 100 mm deep choker layer composed of 20 to 10 mm clean washed HL 6 aggregate shall be placed above the drainage layer to separate the overlaying filter media.
Geotextile and Geomembrane Liners	The geotextile should be a non-woven needle punched, or woven monofilament geotextile fabric. Woven slit film and non-woven heat bonded fabrics should be avoided as they are susceptible to clogging.
	A geotextile liner should be specified only along the sides of the bioswale drainage layers to prevent clogging of the aggregate voids, soil slumping, and downward or lateral migration of finer soil particles. If placed incorrectly or around the perimeter of the entire GI facility, it will prevent lateral root growth and as such, is incompatible with growing trees to maturity. Horizontal applications of geotextile should be avoided within the drainage layers due to fabric clogging and greater susceptibility to system failure. In softscape, a geotextile liner should also be installed underneath the rip-rap erosion protection as per drawing T-850.111 to facilitate maintenance activities of the inlet and pre-treatment components.
	An impermeable geomembrane liner should be installed at inlets as per drawing T-850.111 to limit lateral flow underneath abutting roadways, parking lots, or sidewalks, and may be specified if the bioswale is in proximity to structural foundations.
Underdrain (Optional)	Required where native soil infiltration rates are less than 15 mm/hr or the longitudinal slope of the bioswale is less than 1.0%, a 200mm diameter HDPE or equivalent material perforated underdrain pipe should be installed a minimum of 150 mm above the bottom of the drainage layer.
Overflow Outlet Structure	In hardscape, a beehive catch basin as per drawing T-850.091 should be sized and placed in the bioswale facility to safely convey large storm events to the storm sewer. The overflow invert shall be set from 150 mm to a maximum of 600 mm above the filter bed surface. The overflow invert shall also be a minimum of 50 mm below the downstream roadway surface at the outlet.

Parameters	Design Considerations
	In softscape, overflow outlet, that is to say culvert is to be sized to convey larger storm events and set at a maximum of 250mm above the filter bed surface. Culvert headwall is to be cast-in-place or precast concrete with a minimum 150 mm thickness. The culvert header overflow inlet control should be pre-fabricated plastic or metal with a capacity sized based on the receiving culvert.
Water Quality	Similar to the range of bioretention systems, bioswales are capable of achieving effective pollutant removal rates for TSS, hydrocarbons, and metals. Removal rates for bioswales are best enhanced by adequate pre-treatment practices, longitudinal slopes less than 3%, native soil infiltration rates greater than 15 mm/hr, flow velocity less than 0.5 m/s during the 6-hour Chicago storm event, and swale slopes 3:1 (H:V) or less.
Water Balance	Estimated runoff reductions are 85% without underdrains and 45% with an underdrain. These parameter values are greatly influenced by native soil infiltration rates, rainfall patterns, GI sizing, and other environmental factors due to varying site contexts.
Water Surface Elevation	The peak water surface elevation should be kept below critical values that would overtop adjacent sidewalks, roadways, or compromise adjacent structure during the 2-, 10-, and 100-yr design storms.
	The maximum flow depth should typically correspond to two-thirds of the height of the bioswale vegetation, if applicable during the appropriate water quality storm. The recommended maximum flow depth is 100 mm during a 6-hour Chicago storm event.
Drain-down Time	Similar to bioretention facilities, bioswales are preferred to be drained in less than 48hrs; but depending on native soil and underdrain application, time to drain shall be no longer than 96hrs for partial infiltration with a maximum ponding depth less than 300mm. Maximum surface ponding duration is preferred to be less than 24hrs to limit mosquito breeding; however, no longer than 48hrs. For filter media depths less than 1m, a maximum surface ponding of 85 to 100 mm is acceptable.
Velocities and Allowable Release Rates	Bioswale velocities should be kept to non-erosive levels during the 2-yr, 10-yr, and 100-yr design storms. To encourage filtration and water quality benefits, velocities should be maintained at less than 0.5 m/s during the 6-hour Chicago storm event.
	Maximum release rates should be dictated based on allowable, regulated release rates. Release rates should also be limited to increase the hydraulic residence time within the bioswale. Hydraulic residence time should preferably be greater than 9 minutes with a minimum value of 5 minutes if specific water quality targets are to be achieved.

Parameters	Design Considerations
Driveways and Culverts	Driveway culverts to be minimum 300 mm diameter, unless otherwise specified. Culverts shall have minimum 300 mm cover at driveways and 600mm at roadways, unless otherwise specified. The maximum slope from driveway level to ditch invert is 3H:1V. Culvert surround shall be as per OPSD 800 series, with frost protection where required according to OPSD 802.030 or 802.031. Material according to City of Toronto Design Criteria for Sewers and Watermains.

Enhanced Grass Swales

Enhanced grass swales, often referred to as enhanced vegetated swales, are gently sloping and parabolically-shaped open vegetated channels which incorporate amended soils to attenuate stormwater runoff and assist in stormwater runoff treatment. Figure 7 illustrates the cross-section of an enhanced grass swale system and its typical components.

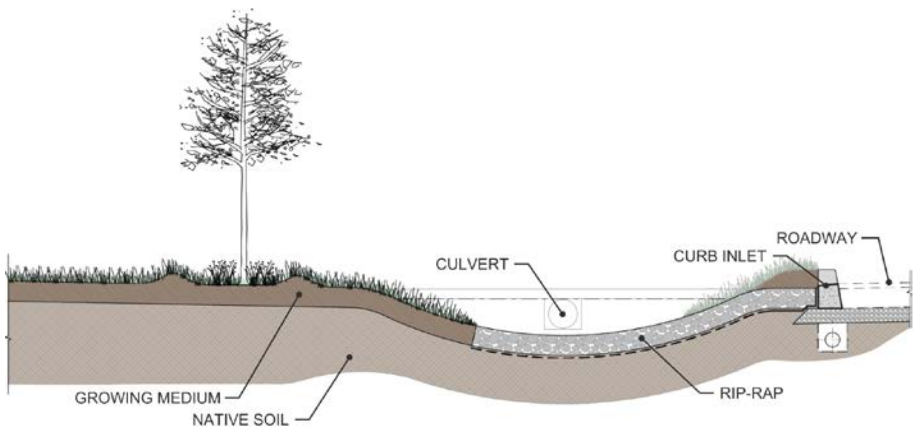

Figure 7: Enhanced grass swale cross-section

Green Infrastructure System Application

Similar to conventional grass channels, ditches, and swales used for roadway drainage, enhanced grass swales can be applied to the right-of-way of roads or along parking lots for stormwater treatment. Enhanced grass swales are preferred over curb, gutter and storm drain infrastructure where development density, topography and depth of water table permits as this GI is more cost-effective, reduces impervious cover, augments the natural landscape, and provides aesthetic benefits to the streetscape.

Consideration should be placed on its orientation, proximity to other structures and/or landscaped features to provide a suitable scale and form for the surrounding features. The topography and soil will determine the applicability of enhanced grass swale designs, as relatively flat slopes and sufficient cross-sectional area are recommended to maintain non-erosive flow velocities. The swale alignment should avoid sharp bends that cause erosion, but may meander to provide aesthetic purpose, follow roadway curvatures, and promote slower flows.

However, due to the generally large area required, enhanced grass swales may not be well suited for retrofit conditions or highly dense, urban environments, unless existing drainage ditches may be properly repurposed. Another common form of urban integration of swales can be as part of a landscaped area within residential and commercial developments.

Depending on the location, these systems provide suitable snow storage area during winter months. Swale slopes are typically designed with shallow gradients that do not present significant risks to public health and safety. Furthermore, enhanced grass swales are primarily intended to safely convey runoff from design storm events to adjacent drainage systems and are not designed to retain stormwater runoff for extended periods of time.

Design Considerations

Several key design considerations should be incorporated into the planning, design, and construction of enhanced grass swale systems:

- Site constraints and topography
- Contributing areas
- Geometry
- Pre-treatment features
- Targeted pollutant removal rates
- Utility coordination
- Conveyance and overflow
- Soil amendments
- Total maximum volume of snow, ice, and water during snow melt periods

Appropriate design parameters can be found in Table 12. Typical details of enhanced grass swales can be referred to in drawing T-850.121.

Table 12: Enhanced grass swale design considerations and site characteristics

Parameters	Design Considerations
Site Topography	Enhanced grass swales are best installed in areas where contributing slopes are between 0.5 to 4.0%, and no greater than 6.0% to prevent ponding and erosion while providing adequate residence time. Check dams are recommended where slopes exceed 3.0%.
Native Soil	Enhanced grass swales can be installed in any type of soil but are recommended to be implemented where native soil infiltration rates are greater than 15 mm/hr. Additionally, infiltration rates may be increased by tilling native soil to a depth of 300 mm below the bottom of the facility.
Groundwater Buffer	The base of the facility should be a minimum of 1m above the seasonal high groundwater level to prevent groundwater contamination.
Bedrock Buffer	Similar to groundwater buffer requirements, bedrock or other impermeable layers shall be no less than 1m below the base of the facility.
Building Setback	Swales should be setback from abutting building foundations a minimum of 4 m to prevent water damage unless otherwise specified by local or provincial building codes.
Utility Coordination	For all utility coordination, it is important to ensure complete and accurate Subsurface Utility Engineering (SUE) information is available for review during design considerations. Designers should approach utility owners during preliminary design regarding allowable horizontal and vertical clearances between the swale and crossing utilities. Utilities should be offset from the centreline of the swale and there are generally no issues with underground utilities below the swale. The clearances to the utilities shall comply with the specified requirements in *Municipal Consent Requirements (MCR)* document. Exemptions to the specified utilities clearance requirements shall be discussed with the utility asset owners. The designer shall propose alternative considerations to meet the expectations of the City and impacted utility asset owners.
Contributing Drainage Area	Enhanced grass swales are capable of handling a varied range of contributing area from a conveyance capacity, if properly designed. In general, a ratio of enhanced grass swale to contributing road surface should equal to 1:1 or greater. However, once contributing areas exceed 2 ha, erosive velocities are commonly encountered and may prove challenging to mitigate.
	Typical impervious drainage area to enhanced grass swale area ratios are between 5:1 and 10:1.

Parameters	Design Considerations
Geometry	Enhanced grass swales are generally designed with a trapezoidal or parabolic cross-section. Trapezoidal swales will eventually evolve into parabolic swales over time; therefore, the design should assume the capacities and conveyances of a parabolic swale.
	The bottom width of the cross section should be between 0.75 m and 3m to permit shallow flows, adequate water quality treatment, and prevent the formation of concentrated flow channels.
	Longitudinal slopes should be slopes between 0.5 to 4%. Check dams should be provided when slopes exceed 3%.
	The length of the enhanced grass swale should be equal to or greater than the length of the contributing roadway length if it is implemented parallel to the roadway to convey and treat its runoff. The swale is recommended to be longer than 30 m to exhibit efficient pollutant removal rates.
	Side slopes should be as flat as possible to maximize filtration properties and to aid lateral inflow. A maximum slope of 2.5:1 (H:V) is recommended to prevent lateral inflow erosion while a 4:1 (H:V) slope is preferred where space permits.
	The typical maximum depth of enhanced grass swales ranges from 400 to 600 mm depending on the application and constraints.
	The length of enhanced grass swales between culverts underneath crossing driveways should be 5 metres minimum for maintenance access purposes.
	Enhanced grass swales should also be of sufficient size to account for combined volumes of snow, ice and melt water during the spring without relying on infiltration.
Pre-treatment	Rip-rap should be placed at inlets where conveyances concentrate to provide erosion protection and pre-treatment functions. Geomembrane liners are to be placed under the rip-rap extending 600mm from the inlet while geotextile fabric shall be placed under the remaining rip-rap as per T-850.121. Sediment pads may also be provided at inlets as a pre-treatment option. Vegetated filter strips with a slope of 3:1 (H:V) can be implemented as pre-treatment features for lateral sheet flows entering the swale.
Filter Media, Planting Soil and Vegetation	Refer to the Common GI Elements section for material specifications for filter media, planting soil, and vegetation. In general, vegetation mainly consists of salt and drought tolerant low meadow grasses and should be maintained at a minimum height of 150 mm.
Geotextile and Geomembrane Liners	A geotextile liner should also be installed underneath the rip-rap erosion protection as per drawing T-850.121 to facilitate maintenance activities of the inlet and pre-treatment components.

Parameters	Design Considerations
	An impermeable geomembrane liner should be installed at inlets as per drawing T-850.121 to limit lateral flow underneath abutting roadways, parking lots, or sidewalks.
Soil Amendments	The growing medium layer on the filter bed of the enhanced grass swale should be 300 mm in depth. Highly compacted soils or soils with low fertility where vegetation growth is impeded should be tilled to its full depth (300mm) and amended with compost to achieve an organic content of 8 to 15% by weight or 30 to 40% by volume.
Overflow Outlet Structure	A beehive catch basin as per drawing T-850.091 should be sized and placed at a downstream location within the enhanced grass swale to safely convey large storm events to the storm sewer. The overflow invert shall be set a minimum of 50 mm above the filter bed surface but typically ranges from 150 mm to a maximum of 600 mm.
Water Quality	Median pollutant removal rates determined through research studies include 76% of TSS, 55% of TP, 50% of TN, and 60% of total zinc and copper. Removal rates for swales are best enhanced by adequate pre-treatment practices, native soil infiltration rates greater than 15 mm/hr, longitudinal slopes less than 1%, flow velocity less than 0.5 m/s during the 6-hour Chicago storm event, and swale slopes 3:1 (H:V) or less.
Water Balance	Estimated runoff reductions are 20% on hydrologic soil groups A and B and 10% on hydrologic soil groups C and D (Refer to Table 10 for hydrologic soil group definitions). Greater reductions are achieved when soils are tilled to a minimum of 300mm and amended to consist of organic content of 8 to 15% by weight or 30 to 40% by volume is recommended.
Water Surface Elevation	The peak water surface elevation should be kept below critical values that would overtop adjacent sidewalks, roadways, or compromise adjacent structure during the 2-yr, 10-yr, and 100-yr design storms.
	The maximum flow depth should typically correspond to two-thirds of the height of the bioswale vegetation, if applicable during the appropriate water quality storm. The recommended maximum flow depth is 100 mm during a 6-hour Chicago storm event.
Drain-down Time	Enhanced grass swales are to be drained in less than 48hrs after a 2-yr design storm event with a maximum ponding depth less than 300 mm. Maximum surface ponding duration shall be 24hrs to limit mosquito breeding.
Velocities and Allowable Release Rates	To encourage filtration and water quality benefits, velocities should be maintained at less than 0.5 m/s during the 6-hour Chicago storm event. The enhanced grass swale should also be designed with a

Parameters	Design Considerations
	capacity to convey locally required design storm (10-yr) at non-erosive velocities.
	Maximum release rates should be dictated based on allowable, regulated release rates. Release rates should also be limited to increase the hydraulic residence time within the swale. Hydraulic residence time should preferably be greater than 9 minutes with a minimum value of 5 minutes if specific water quality targets are to be achieved.
Driveways and Culverts	Driveway culverts to be minimum 300mm unless otherwise specified. Culverts shall have minimum 300mm cover at driveways unless otherwise specified. The maximum slope from driveway level to ditch invert is 3H:1V. Culvert surround shall be as per OPSD 800 series, with frost protection where required as per OPSD 802.030 or 802.031. Material as per City of Toronto Design Criteria for Sewers and Watermains.

Green Gutter

Green gutters are defined as shallow planters with low-growing grasses or sedums that extend the full length of a street section. The system is intended to provide water quality treatment of stormwater runoff from adjacent streets and walkways. Figure 8 and Figure 9 illustrates the cross-section of a green gutter system and its typical components.

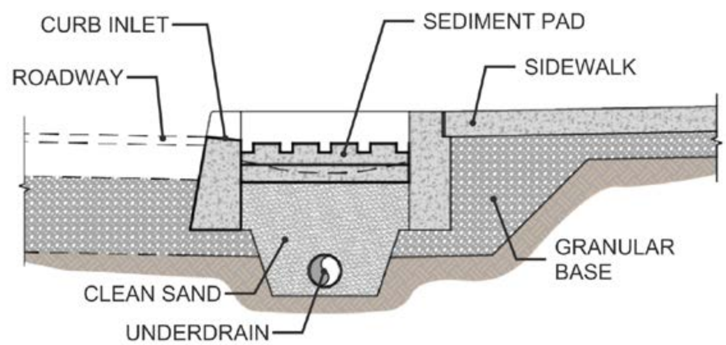

Figure 8: Green gutter cross-section with inlet and sediment pad

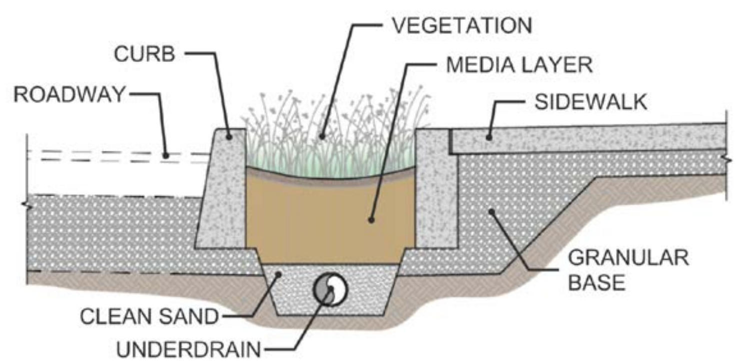

Figure 9: Green gutter cross-section with planting

Green Infrastructure System Application

This system is typically used within the right-of-way of roadways as a separation feature between different modes of transportation such as cycling, vehicular, and/or LRT infrastructure. Green gutters are easily adaptable within urban or highly space-constrained contexts as they are very narrow – typical maximum width of 1m, provides safety buffers, and adds attractive aesthetic value to the surrounding streetscape. The facilities may run continuously along the lengths of blocks while integrating breaks at intervals to accommodate pedestrian movement. In general, green gutters should be planned and designed emphasizing safety by accommodating necessary pedestrian traffic and flow through a district. Green gutters should be considered as a means to separate bike lanes and vehicles lanes on roadways.

Vegetation planted in the green gutter should be salt-tolerant and function to attenuate, filter, and infiltrate stormwater runoff. Consideration for reducing the amount of de-icing substances used on contributing hardscape areas is important to preserve the vegetation within the green gutter. Green gutters are also a suitable area for snow storage during the winter.

Design Considerations

Several key design considerations should be incorporated into the planning, design, and construction of green gutter systems:

- Site constraints and topography
- Contributing drainage areas
- Targeted pollutant removal rates
- Utility coordination
- Permissible velocity levels
- Vegetation selection
- Total maximum volume of snow, ice, and water during snow melt periods
- Soil infiltration rates

Appropriate design parameters can be found in Table 13. Typical details of green gutters can be referred to in drawing T-850.141.

Table 13: Green gutter design considerations and site characteristics

Parameters	Design Considerations
Building Setback	Green gutters should be setback from abutting building foundations a minimum of 4 m unless otherwise specified by local or provincial building codes. The use of an impermeable liner and underdrain system may allow placement within the setback requirement subject to obtaining necessary approvals.
Utility Coordination	For all utility coordination, it is important to ensure complete and accurate Subsurface Utility Engineering (SUE) information is available for review during design considerations. Designers should approach utility owners during preliminary design regarding allowable horizontal and vertical clearances between the green gutter and crossing utilities. Utilities may be allowed to cross through the facility provided suitable protection measures are implemented and allowable cover is maintained. The clearances to the utilities shall comply with the specified requirements in Municipal Consent Requirements (MCR) document. Exemptions to the specified utilities clearance requirements shall be discussed with the utility asset owners. The designer shall propose alternative considerations to meet the expectations of the City and impacted utility asset owners.
Contributing Area	Green gutters are similar to normal concrete gutters and are designed with a capacity to accommodate stormwater runoff from the crown to the right-of-way line of adjacent contributing roadways.
Geometry	Green gutters should be made as wide as possible within the available right-of-way. The maximum width of the filter bed should be 1m, excluding curb widths.
	The length of green gutters is established based on requirements for pedestrian crossing access and the length and width required to adequately facilitate stormwater quality treatment of the contributing drainage area. Generally, the length of the green gutters should be equal to or greater than the length of the contributing roadway. Breaks are to be integrated within the green gutter for crossings at intersections and transit stops.
	With a maximum width of one metre, green gutters installed on both sides of a roadway can typically accommodate two (2) to four (4) total traffic lanes. Therefore, typical ratios of impervious drainage areas to green gutter footprint surface area ranges from 3.5:1 to 7:1.
	Longitudinal slope of the filter media surface should be horizontal. Periodic drops may be necessary to accommodate the sloped profile of the roadway in a “stair-step” fashion using water control

Parameters	Design Considerations
	structures such as concrete pads and slotted weirs as specified in drawing T-850.141.
	Curb cut inlets shall be minimum 300 mm wide placed at 15m intervals on-centre to convey upstream bypass flows into the green gutter.
Pre-treatment	Sediment pads designed in accordance to the geometry depicted in detail T-850.141 and notch arrangement as per detail T-850.102 should be placed at inlets to dissipate runoff energy and prevent unwanted trash, debris, and sediment from entering the system.
Filter Media, Planting Soil and Vegetation	Refer to the Common GI Elements section for material specifications for filter media, planting soil, and vegetation. In general, vegetation shall include a palette of salt tolerant native grasses and sedums which provide a minimum of 80% coverage.
	The filter media should conform to TS 5.10 with a minimum depth of 450 mm. Infiltration rates shall be between 120 mm/hr and 300 mm/hr. A minimum of 200 mm clean sand layer shall be installed beneath the filter media.
Underdrain	An underdrain should be a 200 mm diameter HDPE or equivalent material perforated pipe located a minimum of 50 mm from the bottom of the drainage layer.
Water Quality Parameters	With adequate vegetation cover and properly installed pre-treatment components, green gutters may deliver upwards to 80% TSS removal.
Velocities, Conveyances, and Overflow	Velocities should be less than 0.3 m/s in planted areas and less than 0.9 m/s in mulched zones. Erosion control measures shall be installed at point-source inlets to prevent scour during the 100-yr design storm. Overflow curb cut outlets designed in accordance to drawing T-850.103 shall be placed at downstream areas of the green gutter to convey excess flows out of the system to prevent surface ponding.
Water Surface Elevation	The peak water surface elevation should be kept below critical values that would overtop adjacent sidewalks, roadways, or compromise adjacent structures during the 2-yr, 10-yr, and 100-yr design storms.

Filter Strip

Filter strips are gently-sloping, grassed or similarly vegetated areas that treat runoff as sheet flow from adjacent impervious surfaces. These systems typically comprise of a layer of amended topsoil with increased water-retentive properties to enhance runoff attenuation, sedimentation, filtration, infiltration and evaporation. Figure 10 illustrates the cross-section of a filter strip system and its typical components.

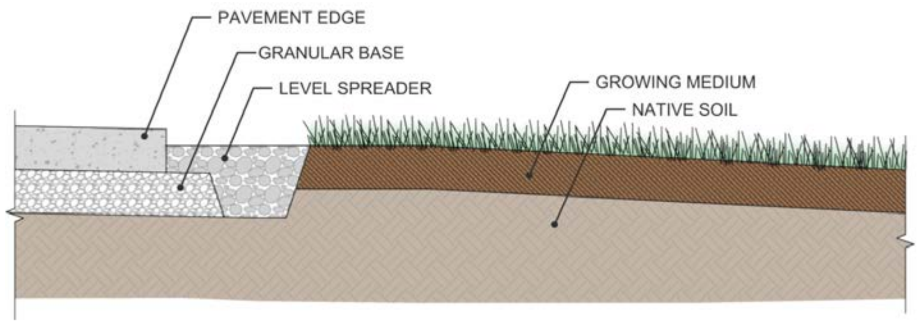

Figure 10: Filter strip cross-section

Green Infrastructure System Application

Filter strips may function as a stand-alone practice or as pre-treatment features where excess water can be conveyed to other adjacent GI or drainage systems. Commonly used for agricultural practices, filter strips have become highly adaptable to the urban context though the integration of other vegetation such as trees, shrubs, and native plants to add aesthetic value in addition to its water quality benefits. However, filter strips may be impractical to integrate within highly dense urban areas since they consume large amounts of space. They are best suited for pre-treatment of roadways, sidewalks, driveways and parking lots or can be used within stream or wetland buffer zones. Level spreaders should be used to disperse concentrated flows from outfalls or roof leaders into sheet flow.

Provided proper application and maintaining consistent sheet flow to the system, filter strip systems reduce the quantity of stormwater runoff and pollutants discharged into the storm sewer systems or receiving waters, for example lakes and rivers. Its applicability and performance are highly dependent on the topography, soils, and vegetation of the site. Furthermore, these systems also provide suitable snow storage area during winter months and often have the capacity for snowmelt infiltration. Snow storage designated filter strips should consist of salt tolerant, non-woody vegetation.

Design Considerations

Several key design considerations should be incorporated into the planning, design, and construction of filter strip systems:

- Site constraints and topography
- Contributing drainage areas
- Targeted pollutant removal rates
- Utility coordination
- Permissible velocity levels
- Vegetation selection
- Total maximum volume of snow, ice, and water during snow melt periods
- Soil infiltration rates

Appropriate design parameters can be found in Table 14. Typical details of filter strips can be referred to in drawing T-850.151.

Table 14: Filter strip design considerations and site characteristics

Parameters	Design Considerations
Site Topography	Filter strips are best used to manage runoff from ground-level impervious areas. They are best installed in areas where contributing slopes are between 1 to 5% to prevent ponding and erosion while providing adequate residence time. Steeper slopes increase the likelihood of erosion and level spreaders are recommended to maintain consistent sheet flow.
Native Soil	Filter strips can be installed in any type of soil. Highly compacted soils or soils with low fertility where vegetation growth is impeded should be tilled a minimum of 300 mm and amended with compost to achieve an organic content of 8 to 15% by weight or 30 to 40% by volume. Refer to TS 5.10 Growing Medium for more information regarding tilling.
Groundwater Buffer	The base of the facility should be a minimum of 1m above the seasonal high groundwater level to prevent groundwater contamination.
Utility Coordination	For all utility coordination, it is important to ensure complete and accurate Subsurface Utility Engineering (SUE) information is available for review during design considerations. Designers should

Parameters	Design Considerations
	approach utility owners during preliminary design regarding allowable horizontal and vertical clearances between the swale and crossing utilities. The clearances to the utilities shall comply with the specified requirements in *Municipal Consent Requirements (MCR)* document. Exemptions to the specified utilities clearance requirements shall be discussed with the utility asset owners. The designer shall propose alternative considerations to meet the expectations of the City and impacted utility asset owners.
Contributing Drainage Area	Filter strips are capable of handling a varied range of contributing area from a conveyance capacity, if properly designed. In general, flow path lengths of the filter strip should exceed the maximum flow path length across the impervious surface (maximum of 25m) draining to it. The maximum slope of the impervious surface towards the filter strip is 3%.
Geometry	The width of filter strips varies but should generally accommodate the width of the impervious surfaces draining to it where space permits.
	Longitudinal slopes should be between 1 to 5%. The recommended maximum slope is 3% as steeper slopes increase likelihood for erosion. Level spreaders should be used in series with greater slopes (5%) to maintain sheet flow.
	The minimum length of filter strips along the flow path is recommended to be 5 m to provide substantial water quality benefits. The maximum length of filter strips is recommended to be 25 m as flows tend to concentrate at this length. Flow path lengths of the filter strip should exceed the maximum flow path length across the impervious surface draining to it.
	Filter strips should also be of sufficient size to account for combined volumes of snow, ice and melt water during the spring without relying on infiltration.
Pre-treatment	A 300 mm wide pea gravel level spreader consisting of 10 to 2.5 mm diameter clean washed crushed aggregate should be used at the impervious surface/GI interface. Level spreaders should be used in series with greater slopes (5%) to maintain sheet flow.
Planting Soil and Vegetation	Refer to the Common GI Elements section for material specifications for planting soil and vegetation. In general, vegetation should be salt and drought tolerant and have an 80% minimum cover to prevent water quality performance decline. A monoculture planting such as turf is the simplest planting approach however mixtures of local native grass and flowering perennials can be introduced for visual interest and wildlife habitat. If the filter

Parameters	Design Considerations
	strip is sufficiently wide, shrub and/or tree planting are also possible.
Soil Amendments	The growing medium layer on the filter bed of the filter strip should be a minimum of 150 mm depth. Highly compacted soils or soils with low fertility where vegetation growth is impeded should be tilled to its full depth (300mm) and amended with compost to achieve an organic content of 8 to 15% by weight or 30 to 40% by volume. The growing medium pH shall be between 6.0 and7.8 and the infiltration rate shall be greater than 120 mm/hr. Refer to TS 5.10 Growing Medium for more information regarding soil amendments.
Water Quality	Standalone filter strips are generally not capable of achieving high pollutant removals, but they serve as a suitable method of pre-treatment for other stormwater GIs. Depending on the length of the practice, pollutant removal rates achieved by filter strips can range from the following: TSS (20 to 80%), TN (20 to 60%), TP (20 to 6%) and total heavy metals (20 to 80%).
Water Balance	Estimated runoff reductions are 50% on hydrologic soil groups A and B and 25% on hydrologic soil groups C and D (Refer to Table 10 for hydrologic soil group definitions).
Velocities and Allowable Release Rates	To encourage filtration and water quality benefits, velocities should be maintained at less than 0.5 m/s during the 6-hour Chicago storm event. The filter strip should also be designed with a capacity to convey locally required design storm (10-yr) at non-erosive velocities.
	The filter strip should maintain the acceptable velocity (0.5m/s) as sheet flow until reaching a swale or other downstream GI/drainage system. Standalone filter strips should incorporate a 150 to 300 mm high pervious berm composed of sand and gravel at the toe of the slope to allow for shallow ponding of runoff.

Permeable Pavement

Permeable pavement systems are hardscaped surfaces designed with sufficient void spaces that allow rainwater to percolate through the media layers. Examples include Permeable Interlocking Concrete Pavers (PICP), porous asphalt, or pervious concrete. These systems can be designed to accommodate full, partial, or no infiltration depending on required performance and site-specific considerations. Figure 11 and Figure 12 illustrates permeable interlocking concrete pavers in a roadway and boulevard context, respectively; Figure 13 illustrates porous asphalt in a roadway context; while Figure 14 and Figure 15 illustrates pervious concrete in a laneway and boulevard context, respectively.

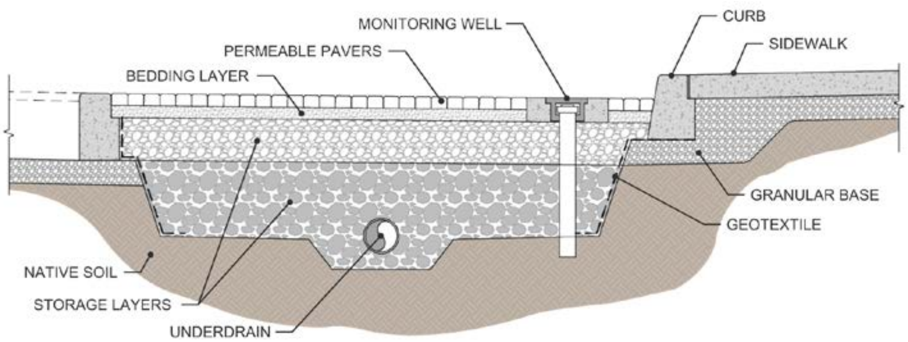

Figure 11: Permeable interlocking concrete pavers in roadway

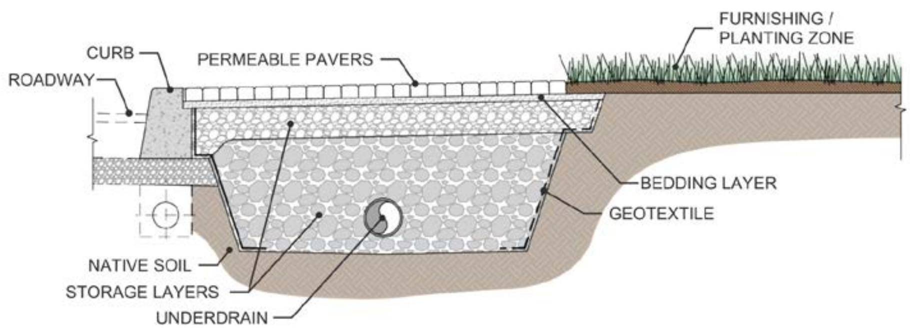

Figure 12: Permeable interlocking concrete pavers in boulevard

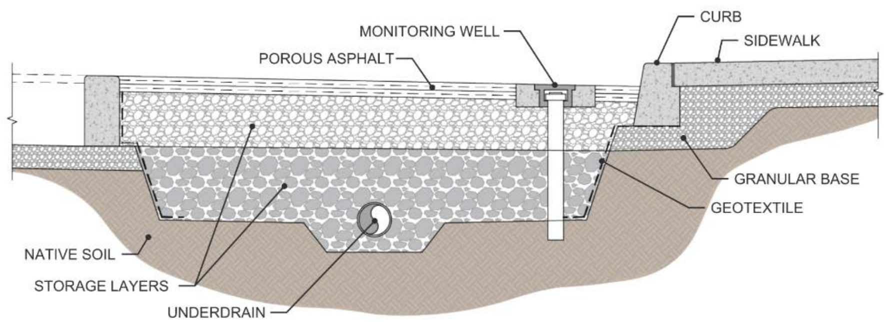

Figure 13: Porous asphalt in roadway

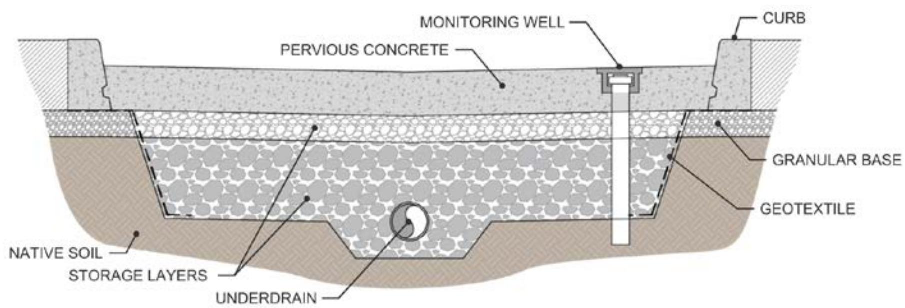

Figure 14: Pervious concrete in laneway

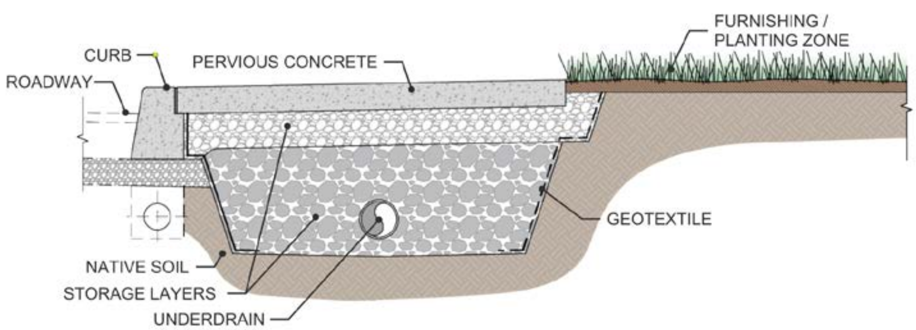

Figure 15: Pervious concrete in boulevard

Green Infrastructure System Application

Permeable pavement systems are best suited for low traffic areas not subject to high-axle loads. They are typically installed in low traffic roadways, driveways, parking lots, and pedestrian/bicycle pathways. They are well suited for retrofit applications, especially as implemented during planned work on existing paved areas.

When properly designed, permeable pavements are well suited for winter climates and do not show degradation in performance provided they are properly and regularly maintained. Winter sanding operations should be prohibited where permeable pavement systems are specified. Road salt may still be incorporated into winter operations, but can be limited as the infiltrating capacity of these systems has significantly reduced surface icing as compared to typical pavement systems.

Design Considerations

Several key design considerations should be incorporated into the planning, design, and construction of permeable pavement systems:

- Traffic loading and frequency
- Contributing areas
- Targeted pollutant removal rates
- Native soil infiltration rates
- Depth to seasonal high groundwater level
- Pavement infiltration rates

Appropriate design parameters can be found in Table 15. Typical details of permeable pavement installations can be referred to in drawings T-850.131 to T-850.135.

Table 15: Permeable pavement design considerations and site characteristics

Parameters	Design Considerations
Site Topography	The slope of permeable pavements should be between 1 and 5%. The impervious areas draining to the permeable pavements should have a slope less than 20%. Pervious surfaces should not drain into the permeable pavement.
	Permeable pavement systems should not be used in high traffic areas or subject to heavy axle loads. They are most suited for low-traffic roadways, driveways, parking lots, and bicycle/pedestrian pathways.
Native Soil	Permeable pavement can be installed in any type of soil capable of withstanding the designed vehicle loading, but if infiltration is incorporated into the design for peak flow rate control or water quality improvements, an underdrain is required where the native soil infiltration rate is less than 15 mm/hr.

Parameters	Design Considerations
	For installations where contact with anti-skid material is expected, an underdrain shall be required where the native soil infiltration rate is are less than 26mm/hr.
	For installations where the total contributing area is greater than 4 ha, an underdrain shall be required where the native soil infiltration rate is less than 35 mm/hr.
	Subgrade infiltration capacity shall be determined by field testing and be based on the compacted state if required for structural support. Appropriate safety correction factors should be used to reflect the compacted conditions.
Groundwater Buffer	Seasonal high groundwater level shall be no less than 1m below the base of the facility.
Bedrock Buffer	Similar to groundwater buffer requirements, bedrock or other impermeable layers shall be no less than 1m below the base of the facility.
Traffic Loading	The permeable pavement system must be designed to meet City of Toronto loading requirements for the type of road. The designer should consider the stop/start nature of traffic at the site, that is to say if at intersection or stop sign as this may limit the lifecycle of the system.
Building Setback	Permeable pavements should be downslope of building foundations. No setback is required if the permeable pavement does not receive flows from other surfaces. Otherwise, a minimum of 4m down-gradient from building foundations is recommended unless otherwise specified by local or provincial building codes.
Utility Coordination	For all utility coordination, it is important to ensure complete and accurate Subsurface Utility Engineering (SUE) information is available for review during design considerations. Designers should approach utility owners during preliminary design regarding allowable horizontal and vertical clearances between the permeable pavement and crossing utilities. Typical requirements are no different from conventional pavement installations; however, as permeable pavement systems have deeper cross-sections, utilities may need to be installed deeper to meet cover requirements.
Contributing Drainage Area	Total contributing impervious areas to permeable pavement systems should be limited to 1.2 times the surface area of the permeable pavement system itself. Pervious areas should not be directed to the permeable pavement installation due to the increased risk of premature clogging.
Geometry	The bottom surface should generally be level unless the system is designed for partial infiltration. In such applications, a slight cross slope towards the underdrain shall be incorporated to help convey excess water.

Parameters	Design Considerations
	The longitudinal subgrade slope shall be 0.5 to 2.0% and the recommended PICP surface cross-fall slope should be 0.5 to 1.0% ideally directed towards adjacent landscaped areas.
	Permeable pavement systems are typically rectangular excavations where the length varies based on desired capacity.
Pavement Infiltration Rate	For permeable asphalt or concrete installations, infiltration rates through the surface courses shall be supported through proven manufacturer testing demonstrating a minimum infiltration rate of 280 mm/hr over the expected design life which includes a safety factor of 10.
Edge Restraints	Suitable concrete edge restraints are required to support paver units, withstand temperature changes, vehicular traffic, snow removal equipment, and to prevent the spreading of joints or unravelling of edges. A minimum base of 150mm is required for support.
Monitoring Well	A capped 100mm monitoring well as per detail T-850.041 shall be installed from the surface to the bottom of the facility.
Storage Layers	For PICP applications only, a bedding layer consisting of ASTM No. 8, 5 mm diameter crushed aggregate with a thickness between 40 and 75mm shall be placed under the surface course.
	A granular base layer consisting of ASTM No. 57, 28 to 14 mm diameter clean washed stone is required between the bedding or surface course and granular sub-base layers. The depth varies based on traffic loading conditions and hydraulic storage requirements.
	The gravel storage or granular sub-base layer should be filled with ASTM No. 2, 80 to 40 mm diameter clean washed stone. The depth varies based on traffic loading conditions and hydraulic storage requirements.
Geotextile Liner	A geotextile liner should be specified only along the sides of the drainage layers to prevent clogging of the aggregate voids, soil slumping, and downward or lateral migration of finer soil particles. Other benefits include hydrocarbon reduction from decomposition due to increased concentration of microbial communities on the liner.
	The geotextile should be a non-woven needle punched, or woven monofilament geotextile fabric while woven slit film and non-woven heat bonded fabrics should be avoided as they are susceptible to clogging.
Underdrain (Optional)	If required, the underdrain should be a 200 mm diameter HDPE or equivalent material perforated pipe located a minimum of 50mm from the bottom of the storage layer.

Parameters	Design Considerations
	Underdrain elevation will vary based on desired targets for partial and full infiltration. For more details go to https://sustainabletechnologies.ca/home/urban-runoff-green-infrastructure/low-impact-development/permeable-pavement/ .
Water Quality	Pollution removal rates are highly dependent on the infiltration rate. An estimate of achievable pollution removal percentages for permeable pavements are above 50% for TSS while most hydrocarbons and metals can be removed.
Water Balance	Estimated runoff reductions are 85% without an underdrain and 45% with an underdrain. These parameter values are greatly influenced by native soil infiltration rates, rainfall patterns, GI sizing, and other environmental factors due to varying site contexts.
Drain-down Time	Permeable pavement systems should be designed to preferably fully drain in less than 48 hours and no greater than 72 hours.

Infiltration Trench

Infiltration trenches are underground systems used to treat and temporarily store stormwater below ground in shallow geotextile-lined excavations filled with clear stone, that is to say washed gravel. The temporary storage within the trench allows for the treatment and percolation of stormwater into the underlying native soil. Infiltration trenches can be designed for complete exfiltration or partial exfiltration where remaining stormwater runoff is directed to adjacent drainage systems. They can also be installed individually or in series. Figure 16 and Figure 17 illustrates the cross-section of an infiltration trench and infiltration gallery underneath permeable pavement, respectively.

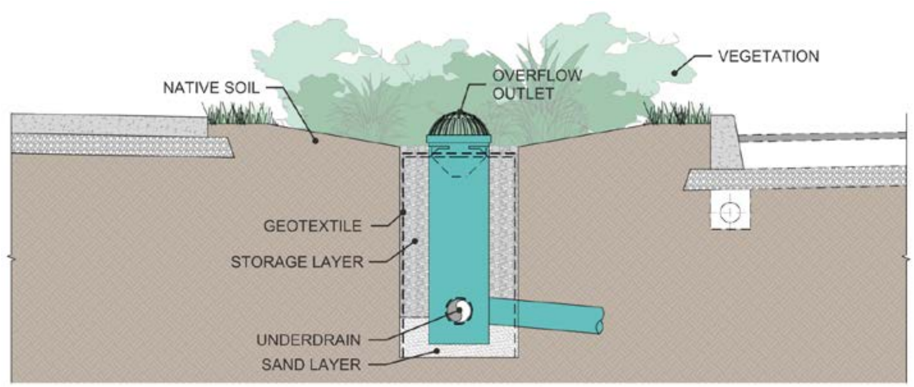

Figure 16: Infiltration trench cross-section

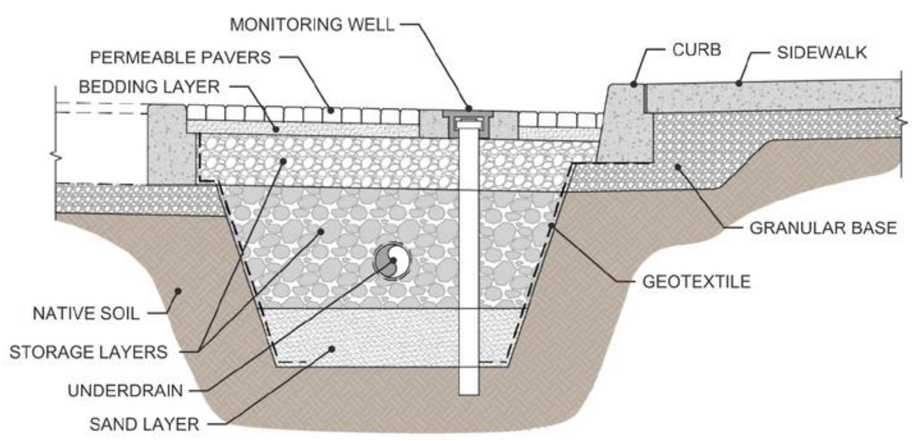

Figure 17: Infiltration gallery under permeable pavement

Green Infrastructure System Application

Infiltration trench systems are effective systems to simulate the natural pre-development hydrologic regime at a site by providing temporary storage of stormwater runoff to encourage the percolation into the native soil. Provided proper practices, infiltration trench systems reduce the quantity of stormwater runoff, pollutants discharged into the storm sewer systems or receiving waters, for example lakes and rivers, and replenish groundwater resources.

Individual infiltration trenches typically service relatively small drainage areas such as individual lots, walkways and roof drainage. However, since most components are located underground, its small surface footprint area is highly adaptable to suit narrow spaces between buildings and along road rights-of-way. Infiltration galleries may be located underneath features such as parking lots, local roads, low to medium traffic highways, parks, rooftop areas, residential developments, and landscaped areas which allows for usage versatility in urban areas. Industrial areas or land uses that produce highly contaminated runoff, for example gas stations and construction sites should not be treated by infiltration trenches to avoid potential groundwater contamination.

To avoid function impairment due to sediment accumulation, infiltration trenches will require acceptable pre-treatment features such as vegetated filter strips to remove as much suspended solids from the runoff as possible before entering the trench. Adequate source controls should be in place to prevent further sediment and contaminants from entering the system. If these measures are appropriately implemented, infiltration trenches can provide effective removal for many pollutants through sedimentation, filtering, and soil adsorption. The groundwater, bedrock, and other impermeable layers govern the feasibility of the system and greater buffer depths provided between the system and these features will reduce the potential for failure.

Design Considerations

Several key design considerations should be incorporated into the planning, design, and construction of infiltration trench systems:

- Contributing drainage area
- Surrounding topography
- Utility coordination
- Required pollutant removal rates (e.g. TSS removal rate)
- Depth to seasonal high groundwater level
- Soil infiltration rates
- Except in wide boulevards, not compatible with planting large growing shade-trees.

Appropriate design parameters can be found in Table 16. Typical details of infiltration trench systems can be referred to in drawings T-850.161 and T-850.162.

Table 16: Infiltration trench design considerations and site characteristics

Parameters	Design Considerations
Site Topography	Infiltration trenches are not recommended to be installed on natural slopes greater than 15%.
Native Soil	Infiltration trenches can be installed over any type of soil but are recommended to be installed over hydrologic soil groups A and B to best achieve water balance targets. For hydrologic soil group definitions, see Table 10.
	Infiltration trenches should typically be installed where native soil infiltration rates are greater than 15mm/hr—hydraulic conductivity greater than 1x10^{-6}cm/s. An underdrain will be required for soil infiltration rates less than 15mm/hr. If possible, install facilities at sites with the highest soil infiltration rates determined through field measurements.
	A minimum of two soil borings should be taken for each infiltration trench. Additional boring locations every 15 m increments for infiltration trenches over 30 m in length. Borings should be taken at the actual location of the proposed infiltration trench so that any localized soil conditions are detected.
Groundwater Buffer	Seasonal high groundwater level shall be no less than 1m below the base of the facility.
Bedrock Buffer	Similar to groundwater buffer requirements, bedrock or other impermeable layers shall be no less than 1m below the base of the facility.
Building Setback	Infiltration trenches should be setback from abutting building foundations a minimum of 4 m unless otherwise specified by local or provincial building codes. The use of an impermeable liner or trench dam (e.g. hard packed clay material or flowable fill) extending the full height of the bioretention facility may allow

Parameters	Design Considerations
	placement within the setback requirement subject to obtaining necessary approvals.
Utility Coordination	For all utility coordination, it is important to ensure complete and accurate Subsurface Utility Engineering (SUE) information is available for review during design considerations. Designers should approach utility owners during preliminary design regarding allowable horizontal and vertical clearances between the infiltration trench and crossing utilities. Considerations for long-term maintenance should be made if infiltration trenches are to be installed near underground utilities.
Contributing Drainage Area	The ratio of impervious drainage area to footprint surface area of the infiltration trench practice should be between 5:1 and 20:1 to limit the sediment accumulation rate. A maximum ratio of 1:10 is recommended for roads and parking lots.
	Contributing area should be restricted to 2 ha or less to avoid problems with infiltrating large volumes in small land areas, that is to say groundwater mounding, compaction/sealing of native soil.
	Infiltration trenches are suitable to collect residential, commercial, and industrial roof runoff. With suitable pre-treatment, trenches may be used for commercial parking lot drainage identified to have minimal contaminants. It is not recommended to implement infiltration trenches for industrial or polluted commercial parking lot land uses due to high potential for groundwater contamination. Pre-treatment is required for direct runoff from roadways into trenches to avoid clogging.
Geometry	Bottom surface should be level.
	The length of the infiltration trench depends on the native soil infiltration rate, porosity of the gravel storage layer media, and the targeted time period to achieve complete drainage between storm events.
	General rectangular practices have a bottom width between 600 and 2400 mm.
	For all native soil types, especially highly permeable soils, that is to say infiltration rate of 45 mm/hr or greater, stone reservoir depth should be a maximum of 2 m to avoid soil compaction and impairing soil permeability.
	The ratio of impervious drainage area to footprint surface area of the infiltration trench practice should be between 5:1 and 20:1 to limit the sediment accumulation rate.
Detention Volume	Infiltration trenches shall be sized to 1) meet allowable ratio of impervious drainage area to footprint surface area, that is to say between 5:1 and 20:1; 2) provide an adequate stone reservoir depth based on groundwater and bedrock constraints; 3)

Parameters	Design Considerations
	accommodate the inflow from the 2-yr, 10-yr, and 100-yr design storm events; and 3) account for combined volumes of snow, ice and melt water during the spring without relying on infiltration.
Pre-treatment	Adequate pre-treatment features are required based on the site context to prevent sediment and debris from entering and impeding infiltration performance. Depending on the context, this may include filter strips, swales, rip-rap, sediment pads with curb cut inlets as per T-850.102, catch basins with underground inlet as per T-850.104, side inlet with trench drains as per T-850.106, trench drain inlets with cleanouts as per T-850.107, screens, and other mechanical devices.
Filter Media, Planting Soil and Vegetation	Refer to the Common GI Elements section for material specifications for filter media, planting soil, and vegetation.
Storage Layers	The gravel storage layer should be filled with 80 to 40 mm diameter uniformly graded, washed stone that provides 30 to 40% void space.
	A 150 to 300 mm sand layer should be located beneath the gravel storage layer and composed of minimal fines and organic matter.
Geotextile Liner	A geotextile liner should be installed around the stone reservoir of the infiltration trench with a minimum overlap at the top of 300mm to allow a separation between two dissimilar soils. This will prevent clogging of the aggregate layer voids, soil slumping, and downwards migration of finer soil particles. Other benefits include hydrocarbon reduction from decomposition due to increased concentration of microbial communities on the liner.
	The geotextile should be a non-woven needle punched, or woven monofilament geotextile fabric while woven slit film and non-woven heat bonded fabrics should be avoided as they are susceptible to clogging.
Underdrain (Optional)	If required, underdrain should be a 200 mm diameter HDPE or equivalent material perforated pipe installed below the frost level and located for full or partial infiltration based on hydraulic requirements. A minimum elevation difference of 1 to 1.5 m between the inflow point and the invert of the downstream storm drain connection is preferred to provide sufficient head.
Inlet and Outlet Structures (If Applicable)	Inlet and outlet pipes with a 200 mm diameter shall be installed below the maximum frost penetration depth to prevent freezing.
	Overflow is not required if soil permeability is greater than 15mm/hr. A beehive catch basin as per drawing T-850.091 should be sized and placed in the infiltration trench to safely convey large storm events to the storm sewer.

Parameters	Design Considerations
Water Quality	An estimate of achievable pollution removal percentages by infiltration trenches include 70 to 90% of TSS, 50 to 70% of TP, 40 to 70% of Total Nitrogen (TN), and 70 to 90% of total heavy metal: such as lead, copper, zinc. These parameter values are greatly influenced by native soil properties, underdrain and pre-treatment.
Water Balance	Estimated runoff reductions are 85% with an underdrain. These parameter values are greatly influenced by native soil infiltration rates, rainfall patterns, GI sizing, and other environmental factors due to varying site contexts.
Drain-down Time	Infiltration trenches are to be drained in <48hrs after a 2-yr design storm event. For infiltration trenches designed to manage the 10-yr and 30-yr event, the half emptying time should occur within 24 hours to be able to manage subsequent rainfall events.
Velocities	Discharge rates should follow maximum overflow or underdrain flow rates in design events 2-yr, 5-yr, 10-yr, 25-yr, and 100-yr.

Glossary

Bioretention Systems – are purposed to temporarily store stormwater runoff, provide filtration through designated filter media, and infiltration into the underlying native soil. They are typically designed as a shallow, depressed planting bed or similar concrete structure to store captured runoff from minor storm events.

Bioswales – consists of linear vegetated channels which convey, treat and attenuate stormwater runoff. The subsurface composition of the system consists of a filter media, storage gallery, and optional underdrain dependent upon native soil infiltration rates.

Boulevard – That part of the public street that is not used, or intended to be used, for vehicle travel by the general public, and that is situated between the travelled portion of the road and the adjoining property line.

Canadian Standards Association (CSA) – is a non-profit organization that oversees the development of voluntary consensus standards for products, services, processes, systems and personnel in Canada.

Catch basin – Box like underground concrete structure with openings in the curb and gutter designed to collect runoff from the streets and the pavement.

Chicago Storm – is a design storm event that corresponds to parameters determined based on Intensity Duration Frequency (IDF) curve relationships.

City – The City of Toronto—the corporation—and will be referred to as the City for the purposes of this document.

Consulting Engineer – A professional engineer or firm of engineers retained by the City or a developer and skilled and experienced in municipal work and land development projects and registered with the Professional Engineers of Ontario.

Continuous Soil Trench (CST) – is a structure designed and built to contain an adequate volume of continuous growing media to support tree growth to maturity under a paved boulevard.

Contract Administrator – the individual or firm responsible for overseeing the construction and administration of the works and representing the City's interest.

Contributing Drainage Area (CDA) – is the total designated area that drains to the GI system, which includes pervious, impervious and the GI area itself.

Detention systems – are designed to collect rainwater and runoff and return it to the City stormwater sewer network at a reduced flow rate and over an extended period to avoid coinciding with the peak stormwater flows experienced within the receiving network.

Enhanced Grass Swales – are slightly sloping and parabolic vegetated channels which incorporate amended soils to slow stormwater runoff and assist in contamination removal.

Erosion and Sediment Control (ESC) – is the process whereby the potential for erosion and/or eroded soil being transported and/or deposited beyond the limits of the construction site is minimized.

Federal Regulations – are laws and requirements governing federal regulatory agency practice and procedures.

Filter Strips – are gently-sloping, densely vegetated areas that treat runoff as sheet flow from adjacent impervious surfaces such as roadways, sidewalks, driveways, and parking lots.

Green Gutters – are shallow vegetated planters extending along the length of a street section with inlets and outlets to convey stormwater runoff. The vegetation and filter media acts to attenuate, filter, and infiltrate the runoff.

Green Infrastructure (GI) – are natural and human-made elements that provide ecological and hydrological functions and processes. Green infrastructure may include components such as natural heritage features and systems, parklands, stormwater management systems, street trees, urban forests, natural channels, permeable surfaces, and green roofs – Toronto Official Plan.

Hydrologic Soil Groups – are four groups are A, AB, B, BC, C and D, where A group soils have the smallest run off potential and highest infiltration rates and D group soils have the highest run off potential and lowest infiltration rates.

Hydrology – is the scientific study of the distribution, movement, and management of water typically performed by hydrologists.

Infiltration systems – are designed to allow collected rainwater and runoff to return to the natural hydrological cycle by infiltrating into the subgrade.

Infiltration Trenches – are underground systems used to treat and temporarily store stormwater below ground in shallow geotextile-lined excavations filled with clear stone (i.e. washed gravel). The temporary storage allows for the treatment and percolation of stormwater into the underlying native soil.

Large or Significant Storm Event – describes a rainfall event during which ≥15mm have been received within 24 hours and/or has an intensity of ≥5mm/hr and during which at least 10 mm have been received.

Lifecycle Activities – in the context of this manual, it includes maintenance (preventative, corrective, and predictive) and monitoring (performance and long-term) activities required to support the GI system over its service life.

Long-Term Monitoring – is monitoring consisting of many of the same parameters used in performance monitoring but extends over many years throughout the GI life cycle.

Maintenance Indicators – two (2) types: visual and testing indicators, used to provide a platform for the assessment of the condition and functional performance of a GI system.

Municipal Consent Requirements (MCR) – City of Toronto document that sets out the process and requirements by which utility companies including City of Toronto utilities and infrastructure, can seek permits to do work in the right-of-way. Appendix O of this document lists the recommended clearances typically required by each utility.

Municipal Regulations – are laws and/or requirements governing municipal regulatory agency practice and procedures.

Natural Heritage System (NHS) – a network of interconnected natural features and areas such as wetlands, woodlands, valley lands, lakes and rivers which support natural processes necessary to maintain biological and geological diversity, natural functions, viable populations of indigenous species and ecosystems.

New Construction – is defined as new greenfield or brownfield development.

Permeable Interlocking Concrete Pavers (PICP) – is a type of permeable pavement consisting of precast modular concrete units and pervious concrete or rubber/plastic composite designed to allow fine, washed aggregate within the joint spacing.

Permeable Pavements – comprise of joints and/or pores which allows water to infiltrate the surface and be temporarily stored within the clear stone (e.g. washed gravel) aggregate base beneath. Water then either percolates into the underlying native soil or is conveyed to other drainage systems via an underdrain.

Pervious Concrete – is a type of permeable pavement which utilizes minimal fine aggregate in combination with a cementitious binder to allow the formation of connected pores within the rigid pavement structure.

Porous Asphalt – is a type of permeable pavement which utilizes minimal fine aggregate in combination with a bituminous binder to allow the formation of connected pores within the flexible pavement structure.

Provincial Regulations – are laws and/or requirements governing provincial regulatory agency practice and procedures.

Provincial Water Quality Objectives (PWQO) – are numerical and narrative criteria for chemical and physical indicators representing a satisfactory level for surface waters, for example lakes and rivers and, where it discharges to the surface and/or the ground water of the province.

Reconstruction – is defined as projects with road realignment and resurfacing, projects with adjustments within the right-of-way that would enable installation of GI, or GI-focused projects where the intent is to specifically add GI to an existing streetscape, even if no other work is ongoing. Reconstruction is typically more invasive than retrofits.

Retrofit – involves changing the systems or structure after its initial construction. Retrofits are typically less invasive than reconstruction.

Right-of-Way – also commonly referred to as the municipal road allowance, refers to City-owned land that includes the roadway and the boulevard. Public utilities are also located within this land – both above and below ground, for example electrical equipment, watermains, gas lines and telecommunication cables and so on.

Routine Operation Inspections – conducted to identify or address when maintenance tasks are needed and to determine when structural repair or further investigations are required to sustain the function of the GI. They should be performed each time a preventive or routine maintenance of the GI is conducted.

Sidewalk – That part of a public street located within the boulevard that is improved for the exclusive use of pedestrians.

Stormwater Tree Trench (STT) – a continuous soil trench that is designed to capture, infiltrate and filter stormwater runoff from a drainage area beyond the footprint of the trench.

SUE – subsurface utility engineering which involves the mapping of underground utilities. There are various quality levels relating to the accuracy and completeness of the information.

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Appendix A – Green Streets Project Selection Process