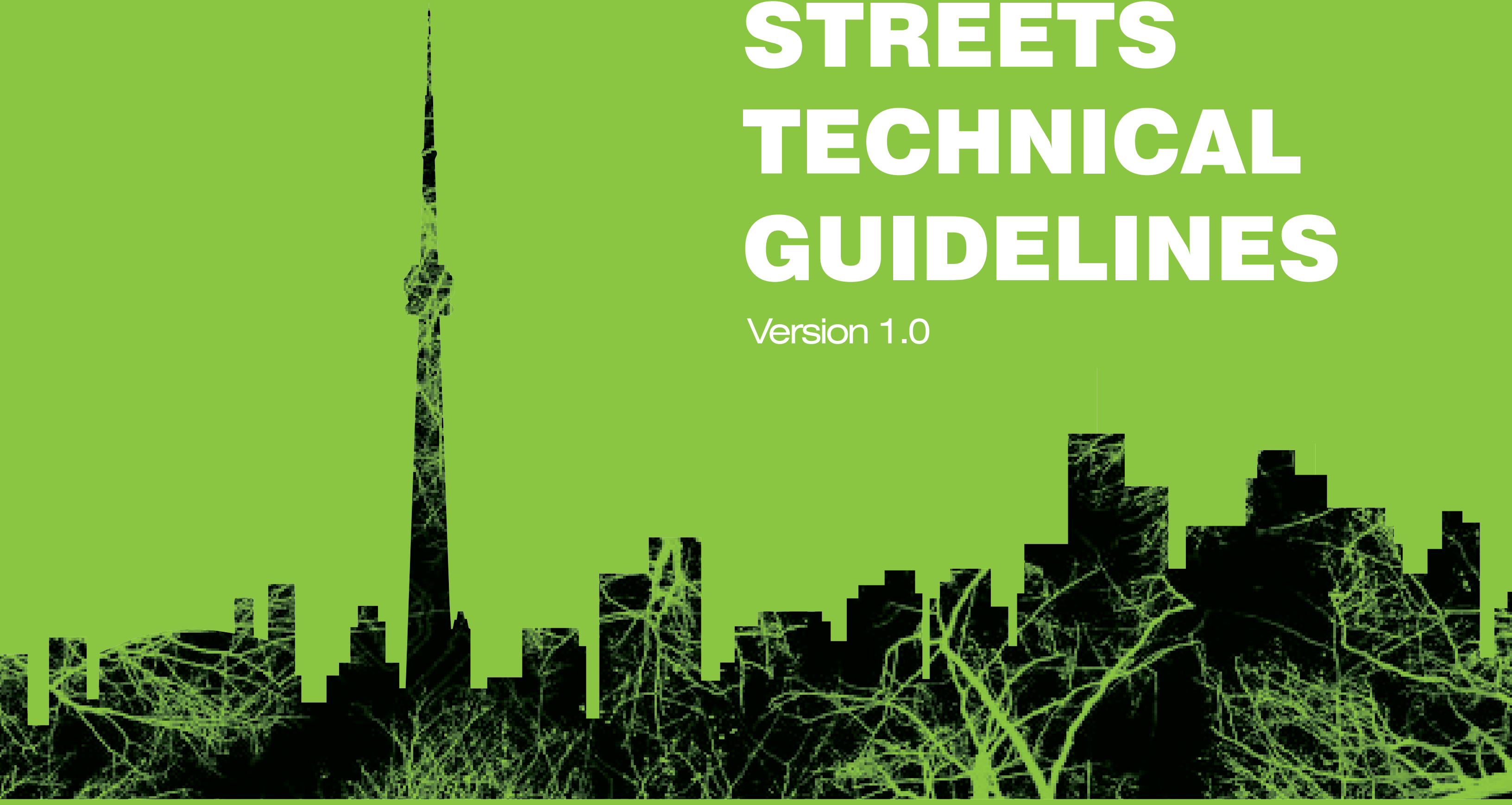
Attachment 1, Part 1

TORONTO

GREEN STREETS TECHNICAL GUIDELINES

Version 1.0



AUGUST 2017

Schollen & Company Inc.
Urban Forest Innovations
TMIG
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TORONTO

ACKNOWLEDGEMENTS

In the efforts to create a resilient city with green infrastructure, the City acknowledges the traditional territory of the Mississaugas of the New Credit, the Huron-Wendat, the Haudenosaunee and home to many diverse Indigenous people.

Working in partnership, meaningful places with green infrastructure can be created to respect and celebrate Indigenous ways and beliefs, improving the quality of life for all our relations, for present and future generations.

Photo Credit: Schollen & Company Inc.

ACKNOWLEDGEMENTS

The **Toronto Green Streets Technical Guidelines (GSTG)** were generated as a product of a thorough and intensive consultation process that involved various City departments as well as utility and service providers and the City of Toronto Complete Streets team. The project was co-led by Sheila Boudreau (Urban Design, City Planning) and Patrick Cheung (Water Infrastructure Management, Toronto Water), with support from Kate Nelischer (Public Consultation, Policy, Planning, Finance & Administration) and Shayna Stott (Strategic Initiatives, Policy & Analysis, City Planning).

Since 2015, stakeholders and City representatives were involved in a series of interview and work sessions in order to provide the Green Streets (GS) consulting team with a better understanding of the specific opportunities, benefits and challenges associated with integrating Green Infrastructure (GI) initiatives into Toronto's streets. The GS consulting team would like to acknowledge the contributions of the following groups. Please refer to Appendix A for a complete list of representatives from each respective group.

GSTG Working Group

GSTG Advisory Group

GSTG Technical Advisory Group

City of Toronto

- City Planning
- Economic Development & Culture
- Engineering & Construction Services
- Environment & Energy
- Parks, Forestry & Recreation
- Policy, Planning, Finance & Administration
- Major Capital Infrastructure Coordination Office
- Solid Waste Management Services
- Toronto Building
- Toronto Water
- Transportation Services

Toronto Hydro

Toronto Parking Authority

Ministry of the Environment and Climate Change

Credit Valley Conservation Authority

Toronto and Region Conservation Authority

Region of Peel

City of Mississauga

Town of The Blue Mountains

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TABLE OF CONTENTS

TABLE OF CONTENTS

SECTION 3.0 | TECHNICAL GUIDELINES Continued

TABLE OF CONTENTS

SECTION 4.0 | SELECTION TOOLS

SECTION 5.0 | OPERATIONS AND MAINTENANCE GUIDELINES

SECTION 6.0 | MONITORING RECOMMENDATIONS

APPENDICES

LIST OF FIGURES & MAPS

FIGURES

MAPS

LIST OF TABLES

TABLES


Photo Credit: Schollen & Company Inc.

ACRONYN AND ABBREVIATIONS

BMP	Best Management Practice
CSG	Toronto Complete Streets Guidelines
CVC	Credit Valley Conservation Authority
ECA	Environmental Compliance Approval
ESA	Environmentally Significant Areas
GHG	Green House Gas
GI	Green Infrastructure
GIS	Geographic Information System
GSTG	Green Streets Technical Guidelines
I&M	Inspection and Maintenance
LED	Light Emitting Diodes
LEED	Leadership in Energy and Environmental Design
LID	Low Impact Development
LRT	Light Rail Transit
MMAH	Ministry of Municipal Affairs and Housing
MOECC	Ontario Ministry of the Environment and Climate Change
NHS	Natural Heritage System
OALA	Ontario Association of Landscape Architects
ODWQS	Ontario Drinking Water Quality Standards
O&M	Operations and Maintenance
OP	Toronto's Official Plan
OPA	Official Plan Amendment
PWQO	Province of Ontario Water Quality Objective
SRI	Solar Reflective Index
STEP	Sustainable Technologies Evaluation Program
SWM	Stormwater Management
TGS	Toronto Green Standard
TRCA	Toronto and Region Conservation Authority
WWFMMP	Wet Weather Flow Management Master Plan

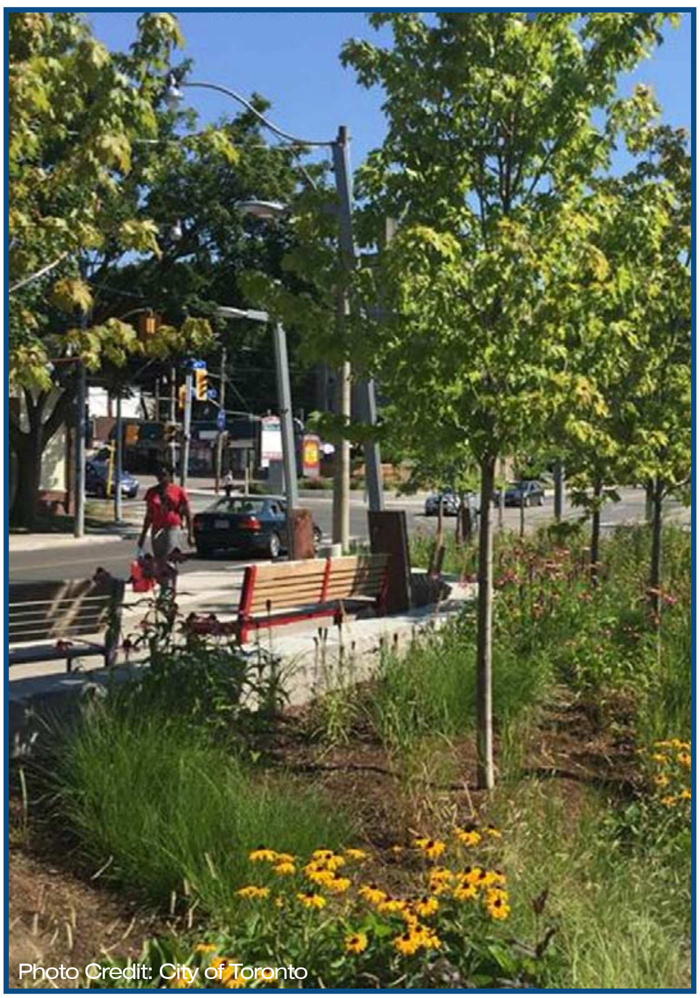
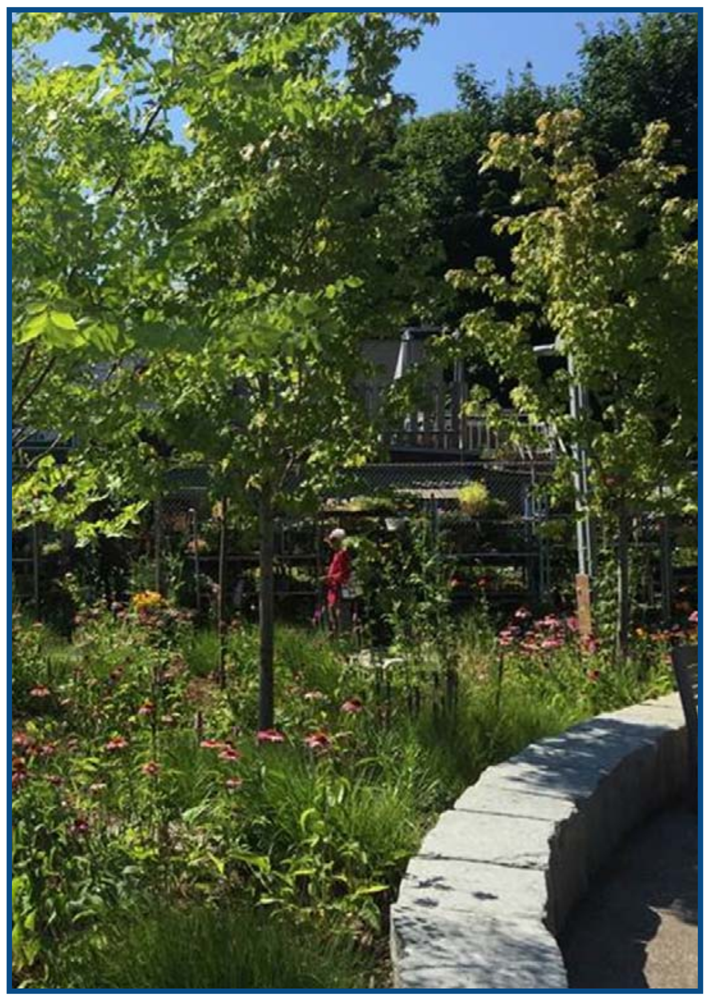


Photo Credit: City of Toronto



EXECUTIVE SUMMARY

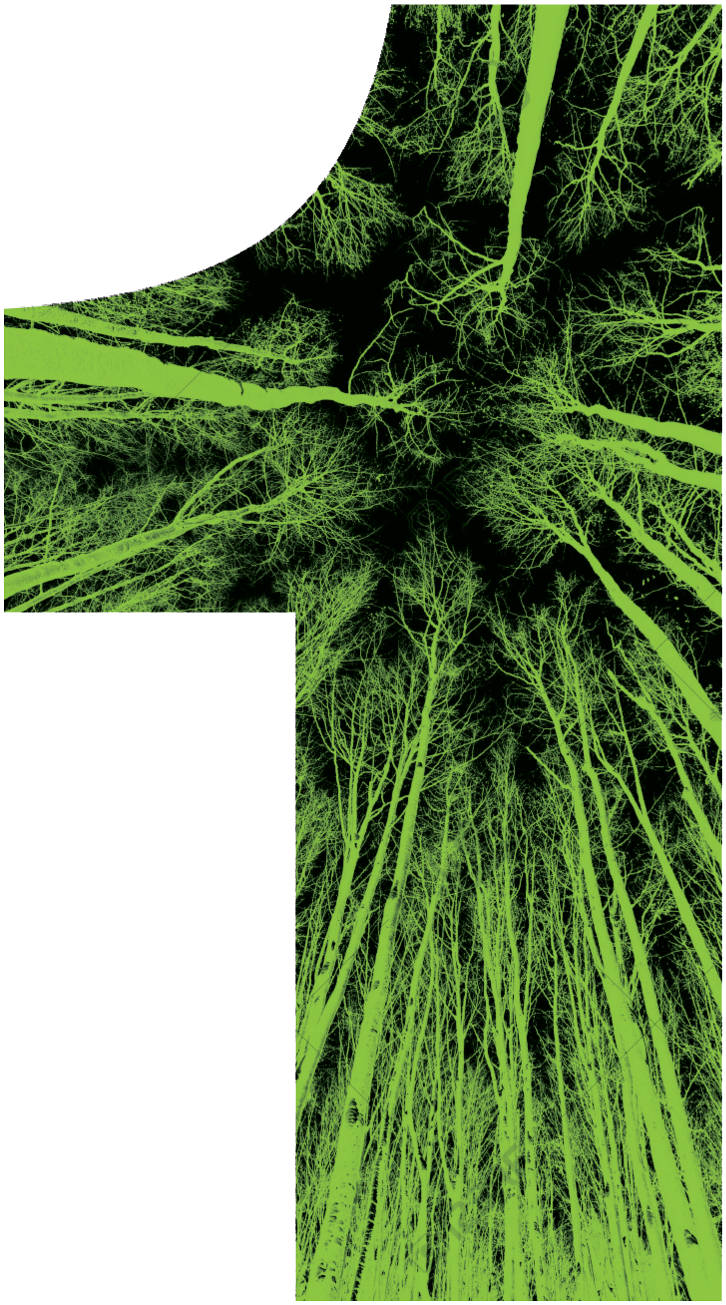
Toronto's Green Streets Technical Guidelines (GSTG) provides direction for the planning, design, integration and maintenance of a range of green infrastructure (GI) options appropriate for Toronto street types and conditions.

The Guidelines were informed by a thorough review of City policy documents, such as the City of Toronto Official Plan, the Toronto Green Standards (TGS), and the Wet Weather Flow Management Master Plan and Guidelines. Research included an analysis of twenty-two precedent manuals and guidelines from municipalities across North America (information provided in Appendix F, Foundational Work). Extensive interviews were conducted with staff from these municipalities, in addition to City of Toronto staff, stakeholders, industry experts and product suppliers, in order to develop a deep understanding of experiences and issues related to green infrastructure in Toronto.

The TGS (a set of performance measures for sustainable site and building design) identifies key environmental pressures which helped categorize the GSTG green infrastructure techniques with direct benefits for: air quality, climate change mitigation and energy efficiency, water quality and quantity management, ecology and solid waste management.

The precedent study produced a 'long list' of forty green infrastructure techniques that are suited to Toronto's geographical and climatic conditions, and thirty-two techniques that are viable for implementation in the City's specific road right-of-way conditions. GI Selection Tools were developed to simplify the process of identifying specific GI options for both new road reconstruction and road rehabilitation projects. Techniques are screened using eleven key parameters, with recommendations provided for scenarios with limited options. A Vegetation Selection Tool was developed to identify appropriate plant species for various GI options (where applicable).

A comprehensive set of technical drawings provide direction on the configuration and layout, construction profile, drainage, conveyance/overflow, monitoring provisions and plant material to assist with design of the GI facilities. Measures required in adopting a life-cycle asset management approach are also provided. Considerations such as operations and maintenance costs, protocols and monitoring recommendations are addressed since these are critical to the long-term effectiveness of every GI practice.



1.0 INTRODUCTION

INFLUENCES

- Boston
- Chicago
- Cleveland
- Edmonton
- Los Angeles
- Milwaukee
- New York
- Omaha
- Philadelphia
- Portland
- San Diego
- Seattle
- US EPA
- Washington
- Toronto Streetscape Manual
- Toronto Ravine Strategy
- Biodiversity in the City of Toronto
- Toronto Climate Change Action Plan
- Toronto Pollinator Protection Strategy
- Tree Planting Solutions in Hard Boulevard Surfaces
- Toronto's Strategic Forest Management Plan 2012-2022
- Toronto Street Trees: Guide to Standard Planting Options
- Wet Weather Flow Management Master Plan
- Best Practices Manual for Green Walls
- TRCA Living Cities Policies
- TRCA LID Inspection and Maintenance Guide
- TRCA Low Impact Development Stormwater Management Planning and Design Guide
- CVC Low Impact Development Stormwater Management Planning and Design Guide
- CVC SWM and LID Monitoring and Preformance Assessment Guide

1.1 PURPOSE OF THE DOCUMENT

In the spring of 2016, the Ministry of Municipal Affairs and Housing (MMAH) approved Official Plan Amendment 262 which modifies Toronto's Official Plan policies and mapping with respect to climate change and energy, the natural environment, green infrastructure and environmentally significant areas (ESAs). Amendment 262 requires: "a healthy natural environment including clean air, soil, energy and water; infrastructure and socioeconomic systems that are resilient to disruptions and climate change; and, a connected system of natural features and ecological functions that support biodiversity and contribute to civic life" (Toronto, Nov. 3, 2015).

The Green Streets Technical Guidelines (GSTG) provide a new standards for development within Toronto's streets. They assist in realizing the City's vision by offering green infrastructure (GI) solutions that can yield significant environmental benefits to relieve urban pressures on ecological systems, improve air quality, achieve energy efficiency and enhance water quality, while ensuring that Toronto's streets remain efficient conduits for vital infrastructure and beautiful, functional corridors for pedestrians, transportation and transit.

The Guideline document was developed on behalf of the City of Toronto to assist City staff, developers and consultants to better understand planning, design, operations & maintenance and monitoring requirements for GI solutions. GI and Vegetation Selection Tools that accompany the document are designed to first identify site specific GI options that are viable for implementation as part of a street retrofit or reconstruction project and then determine plant species that would be context appropriate (where applicable). Guideline drawings provide direction on integration of GI facilities into typical road rights-of-way.

Creation of the GSTG was a complex endeavour that required consideration of the City's foundational documents as identified on the previous page.
The GSTG are aligned with the Toronto and Region Conservation Authority's (TRCA) Living Cities Policies as they advocate for a cleaner, greener and healthier city for future generations. They also support Toronto's Biodiversity, Pollinator Protection and Ravine strategies as well as the City's efforts to reduce greenhouse gas emissions.

GHG Target - reduction of 80% below 1990 levels by 2050.

The Guidelines were informed by precedents and innovative solutions from around the world. Therefore, as technology evolves so too will the Guidelines.

The GSTG is a companion to the CSG and should be consulted concurrently. Together these documents prescribe a holistic approach to the development and renewal of Toronto's streets.

Although the Guidelines have been developed with a specific focus on city streets, they are intended to be applied to various landscapes throughout public and private realms within the City of Toronto.

1.2 GREEN STREETS

1.2.1 | What are Green Streets?

Green Streets are road rights-of-way that incorporate green infrastructure to complement or replace grey infrastructure.

Green Infrastructure (GI), as defined in Toronto's Official Plan, refers to "*natural and human-made elements that provide ecological and hydrological functions and processes"* (Toronto, 2015). Examples of GI options that can be integrated into Green Streets include: street trees, green walls, alternate energy sources (wind / solar) and high efficiency lighting, Low Impact Development (LID) stormwater infrastructure and more.

In addition to supporting the environmental objectives of the TGS, Green Streets are designed to focus on the at-source treatment of stormwater runoff. Green Streets typically employ a 'treatment train' of GI facilities that are designed to replicate the function of a natural drainage system by attenuating, filtering and infiltrating stormwater runoff as close as possible to where it is generated. This approach to managing runoff can reduce or even eliminate the requirement for a conventional (grey infrastructure) stormwater conveyance and management system.

Green Streets help to build a city that is resilient to climate change and contributes to an improved quality of life.

Photo Credit: City of Toronto

1.2.2 | Why do Green Streets Matter?

There are approximately 5,400 ha of roadways in the City of Toronto (Toronto, 2012). With a traditional stormwater pipe conveyance, even a typical rainfall event results in significant concentrations of pollutants entering the City's stream and river systems and ultimately, Lake Ontario. Pollutant concentrations in the stormwater runoff generated by the City's system of roads are estimated to be up to 11,900% greater than the Province of Ontario Water Quality Objective (PWQO) during a typical 25 mm rainfall event.

The following table conveys the total pollutant concentrations that local streams and rivers receive from runoff discharged from Toronto's public roads during one average 25 mm rainfall event.

CONTAINMENT CONTRIBUTION THROUGH ROAD RUNOFF

Fecal Coliform	**500 to 800,000** more counts than recommended for drinking water **50 to 80,000** more counts than recommended for swimming
Suspended Solids (SS)	**117,400 to 253,700 kg**
Total Phosphorous (TP)	**405 to 945 kg** 0-133% more than the PWQO
Phenolics	**19 to 26 kg** 1,300-1,800% more than the PWQO
Lead (Pb)	**51 to 74 kg** 52-120% more than the PWQO
Silver (Ag)	**3 to 7 kg** 1,900-4,900% more than the PWQO
Copper (Cu)	**61 to 62 kg** 800-820% more than the PWQO
Zinc (Zn)	**189 to 351 kg** 367-767% more than the PWQO
Cadimium (Cd)	**1.5 to 32 kg** 400-11,900% more than the PWQO

1.2.3 | Objectives for Green Streets

Specific objectives that can be achieved through the implementation of the Green Streets initiative include:

1. Enhancing the extent and longevity of the urban forest;
2. Mitigating urban heat island effect;
3. Managing stormwater runoff to mitigate flooding and enhance water quality;
4. Promoting infiltration to sustain shallow groundwater systems and maintain interflow patterns;
5. Enhancing air quality; and,
6. Conserving / generating energy.

1.2.4 | Policy Support & Targets

The GSTG have been developed as a tool to assist in achieving the City of Toronto's environmental goals through sensitive integration of Green Infrastructure into the City's network of streets. Support for this initiative has been building over several years from local and provincial levels of government.

In July 2013, City Council directed that *"City Agencies, Corporations and Divisions apply Tier 1 of the Toronto Green Standard, as amended, as the minimum standard to all capital projects "* *(PG25.10).* This was followed by an additional request by City Council in October 2013 for Toronto Water, Transportation Services and City Planning departments *"…to work together to develop 'green infrastructure' standards for the public right-of-way for implementation in Transportation Services and Toronto Water capital projects…"* *(PW25.7)*

In 2014, the Provincial Policy Statement (PPS) stated that "*planning authorities should promote green infrastructure to complement infrastructure"* *(1.6.2).*

In February 2015, the Ontario Ministry of the Environment and Climate Change (MOECC) released an Interpretation Bulletin along with a covering letter that stated, in part, *"…the MOECC's current guidelines and policies support locally derived site-specific performance criteria based on watershed/sub-watershed studies and source control measures such as low impact development (LID)."*

In May 2016, the Ministry of Municipal Affairs and Housing (MMAH) approved Official Plan Amendment (OPA) 262 that focuses on climate change, energy conservation, green infrastructure and the natural environment.

The City’s vision was amended to include the following:

- *a healthy natural environment including clean air, soil, energy and water;*
- *infrastructure and socioeconomic systems that are resilient to disruptions and climate change; and,*
- *a connected system of natural features and ecological functions that support biodiversity and contribute to civic life.*

Revisions in Chapters 2, 3 & 4 of the Official Plan also reinforce climate change mitigation, energy conservation and support for the implementation of GI initiatives in all areas of future development throughout the City. GI is defined in the PPS 2014 as:

> *“Green infrastructure refers to natural and human-made elements that provide ecological and hydrological functions and processes. Components may include natural heritage features and systems, parklands, stormwater management system, street trees, urban forests, natural channels, permeable surfaces and green roofs.”*

CITY OF TORONTO

ENVIRONMENTAL GOALS

GREEN HOUSE GAS EMISSIONS

By 2020 - 30% reduction in greenhouse gas emissions
2020-2050 - 80 % reduction in greenhouse gas emissions
(Toronto Climate Change Action Plan, Current as of June 2007)

URBAN FOREST

Increase tree canopy to 40%
(Toronto’s Strategic Forest Management Plan 2012-2022, Current as of 2013)

TORONTO GREEN STANDARD REQUIREMENTS

Stormwater Retention (Water Balance)*

- Maintain pre-development levels for annual average runoff volumes
- Max runoff to 50% of annual rain fall depth
- Minimum stormwater to be retained on-site = initial rainfall up to 5 mm from all rainfall events

Water Quality (Stormwater Run-off)

- Removal of 80% of Total Suspended Solids from runoff leaving a site
- E. coli <1000 / 100 ml (wet periods during June - Sept) and <100 / 100 ml (dry periods)

(Stormwater performance measures in the TGS are found in the WWFMG, current as of November 2006)*

1.3 HOW TO USE THE GUIDELINES

1.3.1 | Intended Audience

Integration of GI options into Toronto's streets will require a change in how streets are planned, designed, constructed, operated and maintained. The GSTG have been developed to provide guidance to City staff, developers and consultants who are involved in the design, construction, maintenance and operation of Toronto's inventory of streets.

1.3.2 | Applicability

The Guidelines are designed to address both new street construction and street reconstruction projects, as well as rehabilitation and retrofit work within road rights-of-way. The following descriptors define the typical characteristics of New/Reconstruction and Rehabilitation/Retrofit projects:

New and Reconstruction Projects

- Limited combined sewer systems;
- Limited overhead utilities;
- Moderate flexibility in location of underground utilities; and,
- Limited utility relocations at localized areas possible.

Rehabilitation and Retrofit Projects

- Location of overhead and underground utilities is fixed;
- Combined sewers may exist; and,
- Health, maturity and species composition of existing trees must be considered.

GSTG Concept Sample - Bioswale

BEFORE

AFTER

Photo Credit: Schollen & Company Inc.

1.4 DOCUMENT OUTLINE

The GSTG comprise two main components: the Guideline document and the Selection Tools. The document provides technical guidance regarding GI options, while the Green Infrastructure (GI) and Vegetation Selection Tools provide an initial level of site screening that will help users to identify a palette of GI options (and appropriate plant species where applicable) that would be viable given specific site conditions and circumstances. The following outlines the Guideline document. .

Section 2.0 | Green Street Solutions
Green Street solutions consider all Green Infrastructure options that would be viable within a site given its specific characteristics and circumstances. Section 2.0 provides background on the process that was undertaken in order to define a list of GI options that would be viable within Toronto's road rights-of-way. The chapter also addresses climate change adaptation.

Section 3.0 | Technical Guidelines
Section 3.0 describes the integration between the GSTG and CSG and provides a description for each GI option identified in the Selection Tools. Construction considerations and Guideline Drawings are also addressed in this chapter.

Section 4.0 | Selection Tools Outline
As a key element of the GSTG, the GI Selection Tools and associated Vegetation Selection Tool provide efficient means of identifying the most appropriate GI options for a given street condition and context. These Tools are described in Section 4.0.

Section 5.0 | Operations and Maintenance
Proper operations and maintenance is required in order to ensure the longevity and function of GI options. Section 5.0 describes considerations, costs, repairs, replacement and expansion for GI techniques.

Section 6.0 | Monitoring Recommendations
Section 6.0 outlines monitoring objectives, methods, mapping and tracking techniques as well as recommendations to guide integration with other monitoring initiatives/databases.


Photo Credit: City of Toronto

2

2.0

GREEN INFRASTRUCTURE (GI) TECHNIQUES

Photo Credit: Schollen & Company Inc.

2.1 GREEN INFRASTRUCTURE OPTIONS

The GSTG were designed to provide the tools necessary to promote complete street designs that address environmental sustainability as a fundamental tenet for development within the City's rights-of-way.

At the outset of this project, the Green Streets team spent several weeks reviewing precedents from across North America in order to establish a comprehensive list of potential GI options that would be suitable for Toronto's geographical and climatic conditions.

A long list of potential GI options was derived from this background research and then GI practices were organized according to their most relevant Toronto Green Standard environmental driver. For example, street trees provide air quality benefits and are therefore located in the Air Quality section of the list.

TGS environmental drivers include:

- Air Quality;
- Green House Gas Emissions / Energy Efficiency;
- Water Quality, Quantity and Efficiency;
- Ecology; and,
- Solid Waste

As part of the long list, each GI option was described and ancillary benefits outlined. Their suitability for various applications within each Complete Streets type was also considered.

Once the list was established, a 'Considerations' column was added to identify a variety of factors that might restrict or preclude a GI option from becoming a viable candidate for inclusion within the Selection Tool. Each potential GI option was evaluated against a suite of criteria and its feasibility for implementation relative to each proposed 'Application' noted. The 'Rationale' for the selection or the elimination of each GI options was also noted. The resulting short-list of GI options was used to provide a foundation of the GI Selection Tool.

Both the long-list and the short-list of GI options can be found in Appendix B.

Photo Credit: Schollen & Company Inc.

2.2 CLIMATE CHANGE ADAPTATION

According to Toronto's *"Future Weather & Climate Driver Study: Outcomes Report"* (Senes, 2012), over the coming decades, climate change will produce variable weather patterns throughout the City of Toronto. The study projects shorter, milder winters with less snow and more rain; longer growing seasons; and more extreme weather events.

The report predicts that temperatures in the City of Toronto will rise on average 4.4°C by 2049 with winter and summer temperatures anticipated to increase by 5.7°C and 3.8°C respectively. Temperature extremes are expected to increase by 7.6°C with temperatures feeling even hotter as a result of a significant rise in the humidity index. The report also predicts that although storm frequency will be similar or less than it is today, a small proportion of those storms will be extreme events that will produce high volumes of runoff in a very short duration.

Based on these predictions, the City must take aggressive action immediately to not only reduce GHG emissions, but also to adapt to the changes that are forecasted for the coming decades.

The GSTG will contribute to the development of a resilient City by providing a new vision and methodology for design, implementation and care of GI within Toronto's rights-of-way. The Guidelines are consistent with the TGS and seek to:

- Enhance ecology and reduce heat Island effect;
- Protect air quality;
- Manage stormwater quality and quantity; and,
- Reduce greenhouse gases and promote energy efficiency.

Implementation of Green Streets will assist in addressing climate change adaptation challenges by:

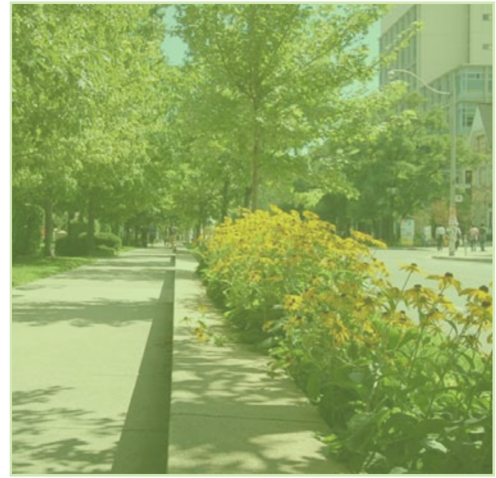
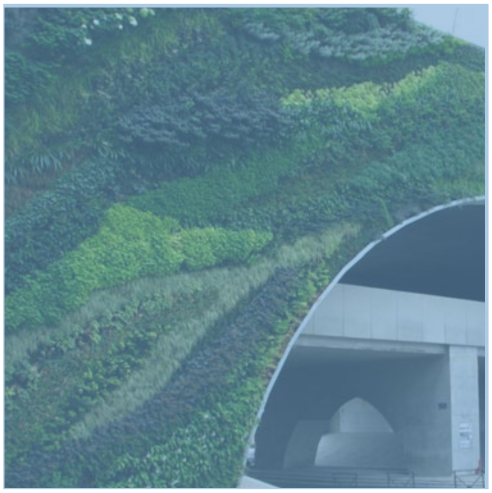
- Facilitating a reduction in GHG emissions that contribute to climate change; and,
- Mitigating the effects of climate change by attenuating and infiltrating stormwater runoff.

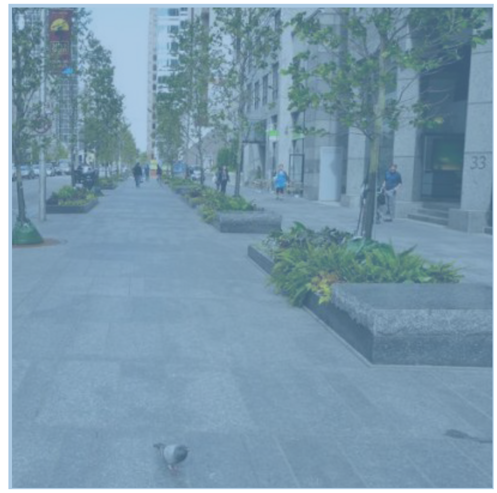
Although stormwater management initiatives proposed in the GSTG may improve the function and resilience of existing stormwater infrastructure by reducing runoff volumes and freeing up capacity within the downstream stormwater drainage system, they will not contribute significantly to mitigating the impacts of extreme precipitation events. Implementation of the GTSG is one of many strategies that must be employed in order for the City to adapt to climate change and to build a more resilient Toronto for the future.

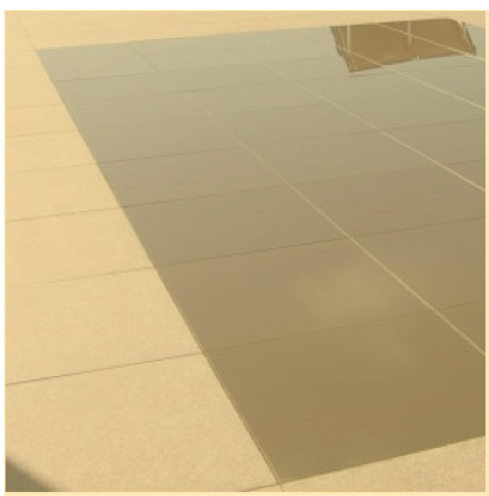
3.0

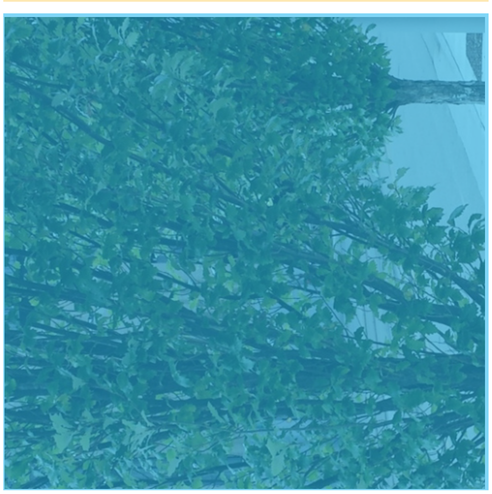
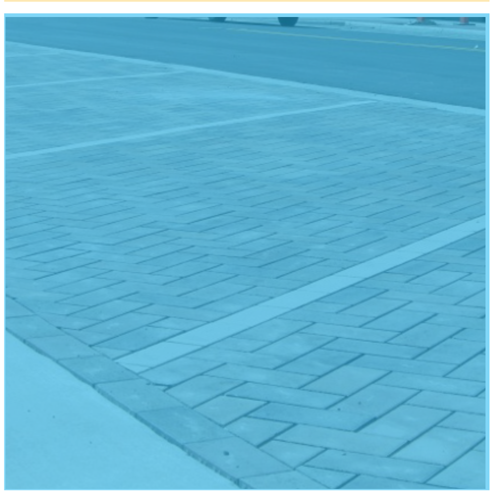
TECHNICAL GUIDELINES








3.1 INTEGRATION OF GREEN STREETS WITH COMPLETE STREETS

The GSTG and the CSG are compatible and complementary documents that have been developed through an iterative process to ensure that Green Street objectives can be achieved across the City's entire portfolio of street types.

Street types presented in the CSG are a key parameter for preliminary screening in the GI Selection Tool. CSG street types are listed in the sidebar to the right.

Applications outlined in the CSG have also been integrated as a parameter in the GI Selection Tool to identify appropriate locations for each GI option within the overall road right-of-way. CGS applications are also listed in the sidebar to the right.

CSG STREET TYPES

1. Civic Street
2. Downtown & Centres Main Street
3. Avenues & Neighbourhood Main Street
4. Downtown & Centres Residential Street
5. Apartment Neighbourhood Residential Street
6. Neighborhood Residential Street
7. Mixed-Use Connector Street
8. Residential Connector Street
9. Scenic Street
10. Park Street
11. Employment Street
12. Mixed- Use Access Street
13. Mixed-Use Shared Street
14. Residential Shared Street
15. Mixed-Use Lane
16. Residential Lane

CSG APPLICATIONS

1. Frontage and Marketing Zones (refer to CSG)
2. Pedestrian Clearway Zone (refer to CSG)
3. Furnishing and Planting Zones (refer to CSG)
4. Edge Zones (refer to CSG)
5. Curbside Space
6. Vehicle Lanes
7. Transit Lanes
8. Medians/Raised Islands
9. On-street Parking
10. Parking Lay-bys
11. Cycling Infrastructure - Separated/Integrated
12. Crosswalks
13. Intersections

ADDITIONAL APPLICATIONS INCLUDE

1. Bridges
2. Feature Paving
3. Street Lights
4. Decorative Lights
5. Parking Meters

3.2 GREEN STREETS TECHNIQUES AND TECHNICAL GUIDANCE

GI options have been categorized according to their association with environmental drivers as outlined in the TGS. The following section provides a description of GI options. GI options marked by an asterisk (*) are emerging technologies for pilot project use only at this time. These techniques may be considered for broad-scale implementation once they have been tested, proven and adopted by the City's various departments.

The list of GI techniques have been organized to correspond with TGS objectives. The following GI Techniques will address ecological priorities within Toronto's streets.

3.2.1 |Urban Forest Canopy

The natural (urban) tree canopy is composed of all layers, leaves, branches and stems, that cover the ground. Tree canopy performs critical ecological functions within the urban environment such as managing stormwater; reducing the urban heat island effect and air pollution and providing wildlife habitat. Enhanced tree canopy also has an aesthetic value, improves quality of life and increases property values.

The City of Toronto seeks to increase tree canopy cover to 40% (Toronto, 2013), therefore designers should look for opportunities to integrate trees within the City's rights-of-way. Tree planting is appropriate within all street types with the exception of residential and mixed-use lanes. Large canopy native species are preferred and the most appropriate species are defined for a specific site application using the Vegetation Selection Tool.

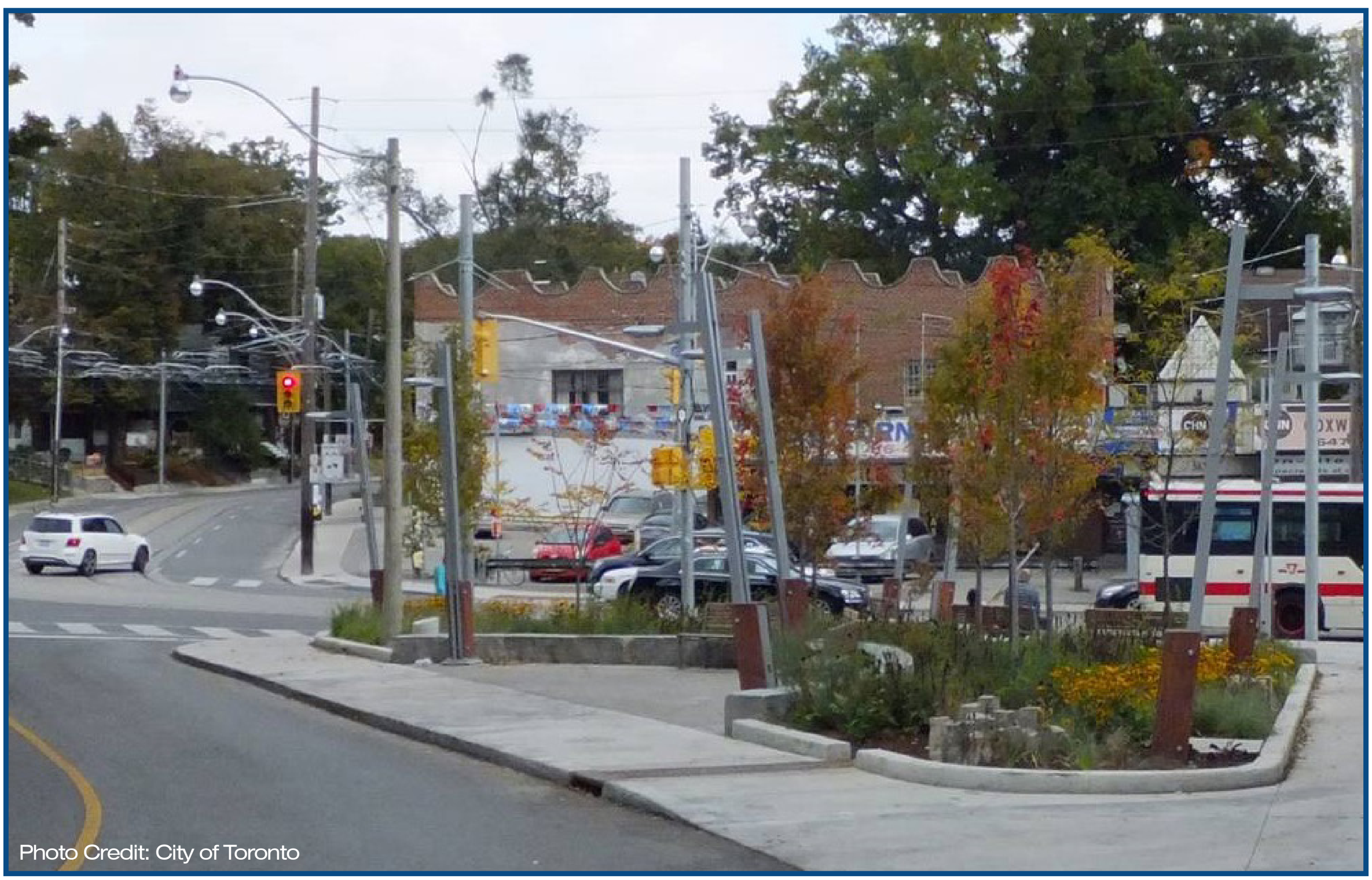


Photo Credit: City of Toronto

3.2.2 | Native Herbaceous Planting

Native herbaceous plants are indigenous to the Toronto region and are characterized by their lack of woody stems above ground level. Herbaceous plant material can be integrated into a variety of GI options to promote pollinator habitat and enhance biodiversity within Toronto's streets. Plant material should not only be selected for its aesthetic quality and habitat value, but also for its tolerance of drought and urban conditions. Refer to the Vegetation Selection Tool for GI and context appropriate plant material.

3.2.3 | Ecopassages

Ecopassages are bridges and tunnel systems that guide animals and reptiles safely over or under roads and highways. Within the City of Toronto, ecopassages can be particularly valuable on streets that bisect the Natural Heritage System (NHS) by facilitating wildlife migration and aiding in the reduction of road mortality. The Toronto and Region Conservation Authority's (TRCA) *Crossings Guideline for Valley and Stream Corridors* (TRCA, 2015) addresses ecopassage design in detail and should be referenced whenever ecopassages are considered for implementation as part of a Green Street project.

"Toronto is home to healthy pollinator populations that support resilient ecosystems and contribute to a rich urban biodiversity."
(Toronto Pollinator Protection Strategy)

Green Infrastructure solutions that feature native herbaceous plants, shrubs and trees can be implemented throughout Toronto's streets to provide key linkages that connect existing pollinator habitats throughout the City.

3.2.4 | Light Limitation

Excessive light stray from street lights can impact wildlife and wildlife habitats. Limiting light dispersion at night can assist in maintaining native wildlife populations, habitats and ecological functions. Every effort should be made on all new street and street retrofit projects to limit light dispersion by making appropriate fixture choices and providing targeted luminaire placement. This is particularly critical on streets that bisect the City's NHS.

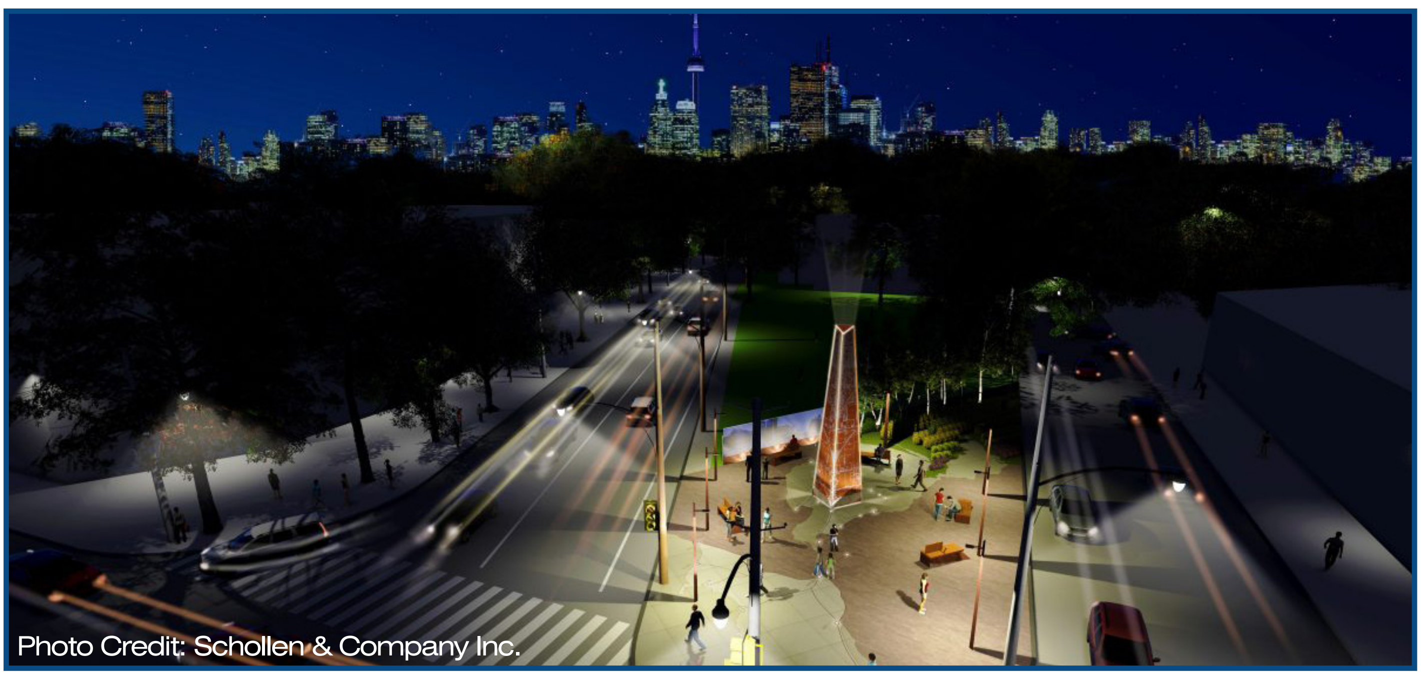


Photo Credit: Schollen & Company Inc.

The following Green Street Options will promote Air Quality as a primary benefit.

3.2.5 | Green Walls

Green walls can provide valuable green infrastructure within confined urban spaces. They can feature plants rooted in the ground and trained to grow up a vertical wall, known as a 'green facade' or plants that are rooted in a vertical modular, composite or custom substrate system that is affixed directly to an existing structural wall, known as a 'living wall'. Refer to Toronto's *Best Practices Manual for Green Walls* (Toronto, 2014) for a detailed description of each.

Green walls provide numerous environmental, social and economic benefits including:

Green walls can be applied to bridge abutments within any street type, but will provide the greatest ecological benefits along streets that are adjacent to or that bisect the NHS. Green walls can also be applied to noise barriers along street corridors to assist with noise attenuation.

Selecting the appropriate green wall system and the appropriate plant materials for a particular site is critical to the long-term sustainability of the green wall. Refer to the Vegetation Selection Tool for an appropriate palette of green wall plant material.

- Promoting biodiversity;
- Providing habitat and nesting opportunities;
- Encouraging ecological linkages;
- Improving air quality; and,
- Providing water quantity and quality benefits.

Photo Credit: Schollen & Company Inc.

3.2.6| Street Trees

Street trees can be planted in hard or soft landscape conditions within frontage zones, furnishing zones or medians of most street types, with the exception of residential lanes and mixed-use lanes.

Street trees help to increase the overall urban forest canopy and can assist in improving air quality, reducing the urban heat island effect and providing wildlife habitat. The City prefers large canopy native species for street tree planting. Suitable species can be identified using the Vegetation Selection Tool.

Planting in grassed areas is easier than in paved conditions, where special construction methods are required. Key areas of concern include the interface between trees and utilities, adequate soil volumes (20-30m^3 /tree) in order to grow trees to maturity and the provision of appropriate structural support in conjunction with non-compacted soils.

The following planting options proposed for the GSTG are adapted from Toronto's *Tree Planting Solutions in Hard Boulevard Surfaces, Best Practices Manual* (Toronto, 2013) and have been designed to meet all criteria noted above.

3.2.6.1| Trees in Soil Cells

Soil cell systems can be used when street trees are desirable in locations where surface areas are limited.

Soil cells are rigid modular systems that are used to increase the soil volume under paved surfaces in ultra-urban areas. They provide the structural integrity required to support vehicular load on paved surfaces while offering up to 92% porous space in order to accommodate underground services and utilities.

Soil cells can be used under conventional concrete or unit pavers as well as under pervious interlocking concrete pavers. In addition, given their structural integrity, soil cells be used under vehicular load bearing sidewalks, parking lay-bys or cycling infrastructure to increase soil volumes.

Paved surfaces should be designed to withstand loads from sidewalk ploughs and midsize service vehicles, therefore, structural soil can be used under paved areas to allow for roots to grow into adjacent soil volumes.

Planting options adopted by the GSTG include:

- Trees in Soil Cells; and,
- Trees in Open Planters.


Photo Credit: Schollen & Company Inc.


Photo Source: Schollen & Company Inc.

3.2.6.2 | Trees in Open Planters

Open tree planters can be used in Planting/ Furnishing Zones, Frontage Zones and Medians where widths are more generous. They are able to accommodate two or more trees per planter and can be framed by a low curb or higher seat wall. Open tree planters are typically the most cost effective way to plant in a hard landscape if space allows, but are not the preferred solution in areas with high pedestrian volumes. The soil volume can also be augmented by installing soil cells below the grade of the planter.

3.2.6.3 | Planter Boxes / Movable Planters

Planter boxes are available in a variety of forms and materials and can be used as accents in Frontage or Furnishing Zones or for buffering between competing uses like Cycling Infrastructure and Vehicle Lanes. Planter boxes can enhance biodiversity and improve air quality, but have a limited ability to manage stormwater as they only receive direct rainfall and have a limited capacity for volume retention.

3.2.6.4 | Precast Tree Planters

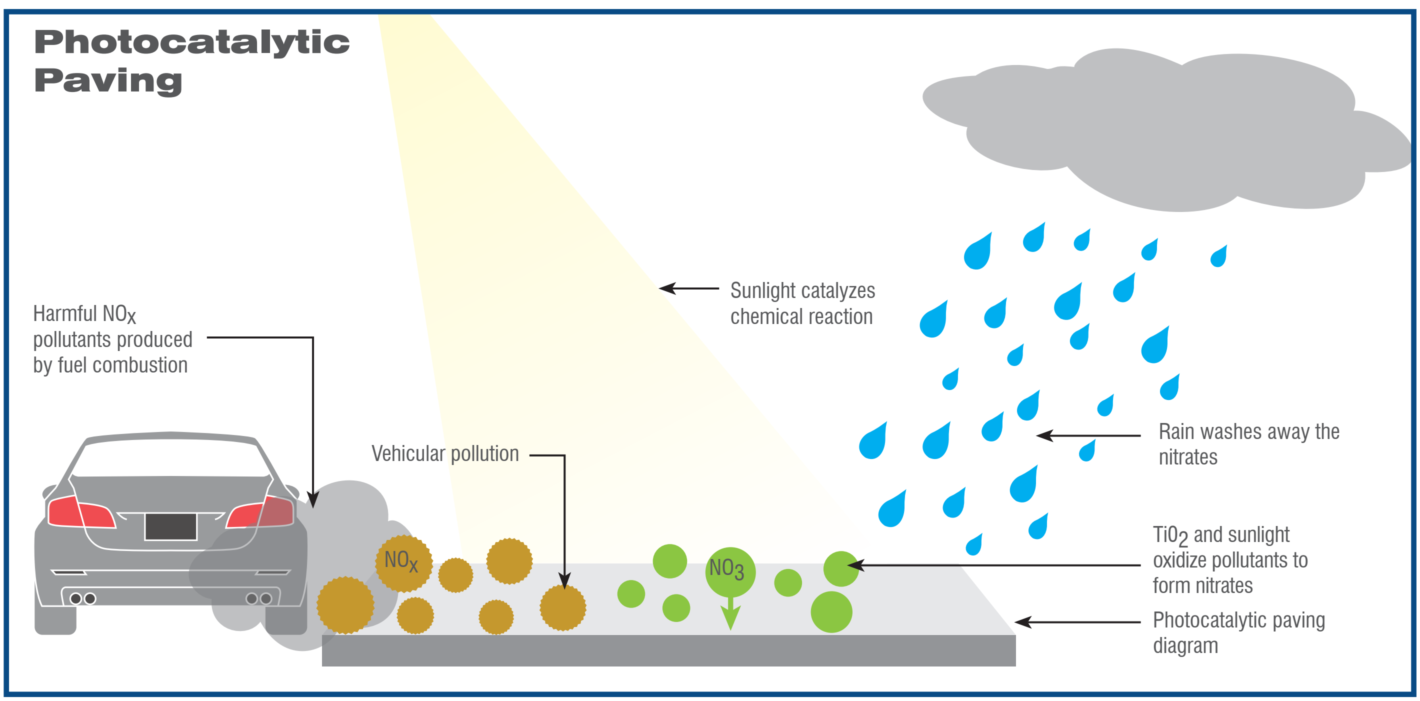
Precast tree planters are prefabricated impervious planters filled with bioretention media and equipped with a perforated pipe outlet for filtration and conveyance of direct rainfall. Precast planters are suitable for use throughout urban street types, however they have a limited capacity for volume retention.

3.2.7| Photocatalytic Paving*

Photocatalytic paving is a surface treatment that has the ability to purify outdoor air by eliminating airborne toxins that result from traffic emissions. When exposed to sunlight, the titanium dioxide embedded within the paving surface generates a chemical reaction that converts nitrogen oxide gasses to non-toxic nitrates that wash away when it rains.

Photocatalytic paving is currently being tested for vehicular and pedestrian applications with promising results. Once this product becomes widely available, it could provide a significant improvement in air quality and therefore should be considered for a variety of paving applications within all street types throughout Toronto.

Photocatalytic Paving



Data Source: Intect Open Science - Open Minds

The following GI options will assist in addressing GHG and Energy Efficiency priorities within Toronto's streets.

3.2.8 | LED Lighting*

LED (light emitting diodes) lights represent the latest in lighting technology. They are long lasting (30,000-60,000 hours) and are extremely energy efficient (up to 90% more efficient then conventional incandescent bulbs). In addition, they generate very little heat and are made of non-toxic materials that can be recycled. LED lights provide superior visibility with more even light dispersion and can reduce light pollution through appropriate fixture choices and targeted placement.

Photo Credit: Sc[illegible] & Company Inc.

3.2.9 | Solar Photovoltaic Panels*

Photovoltaic panels harness sunlight and convert it to usable energy. Solar units can be used to power streetlights and parking meters, to illuminate transit stops and as decorative paving. They provide considerable benefits over conventional grid-powered systems including energy efficiency, location flexibility and wireless monitoring capability. However, due to the fact that many of Toronto's streetlights, parking meters and transit stops are privately-owned and operated, service agreements will be required in order to facilitate the use of solar panels.

3.2.10 | Solar Roads*

Solar roads are a new and evolving technology currenty in research and development in the United States. They comprise a modular system of photovoltaic panels designed to convert sunlight to usable energy.

Solar roads are engineered to be an all-in-one product that will eliminate requirements for resurfacing, repainting and even winter maintenance. LED lights are embedded within the panels to allow for lane markings, turning arrows, HOV, cycling infrastructure or any other type of marking. These markings are illuminated on the surface of the panels as required.

Solar road panels are made from tempered glass that has the traction of asphalt and can support the weight of a semi-truck. They are also self-heating to prevent snow and ice accumulation thereby reducing winter maintenance costs. The panels are equipped with microprocessors that enable communication with each other, operators and users.

Solar roads are not yet widely available, but have been implemented using grants from the United States government and are currently being tested on driveways and parking lots throughout the USA. This product may be a few years away from broad-scale implementation, however once more widely available and proven, they will be worthy of consideration for application throughout all of the City's street types. Solar roads hold the potential to yield significant financial and environmental benefits.

3.2.11| Solar Paver Lights*

Solar-powered LED paver lights are designed to withstand most vehicle traffic and are durable under harsh winter conditions. Each unit is self-contained and comes equipped with its own solar cells that charge an internal battery. A light sensor is included to activate and deactivate the LED lights at dusk and dawn. These pavers are well-suited for application as accent lights within the Frontage Zones, Furnishings Zones or Medians of ultra-urban street types.

Photoluminescent road markings can be used within Vehicular Travel Lanes or to define Crosswalks and Cycling Infrastructure in almost all street types

3.2.13| Wind Energy*

Small-scale wind turbines can be highly versatile and can provide a renewable energy source. Wind turbines are recommended as a sustainable option to power street lights, however given that the majority of Toronto's

Photo Credit: Smart Highway by Studio Rossegaarde and Heijmans

3.2.12| Photoluminescent Road Markings*

Photoluminescent road markings are created from a paint product that has an embedded photoluminescent powder. The paint absorbs sunlight during the day and then emits a green glow at night that lasts up to 10 hours. This type of road marking system can help to reduce street lighting requirements thereby improving energy efficiency.

3.2.14| Cool Pavements*

Pavement with higher solar reflectivity reduces local heat island effects and reduces the heat transferred to stormwater thereby improving water quality. Currently, the TGS Tier 2 and LEED support a requirement for SRI of at least 29 for 75% of all hard landscape surfaces.

The following GI options are designed to promote water quality improvement, quantity control and efficiency within Toronto's streets.

3.2.15 | Bioretention

Bioretention is a Low Impact Development (LID) practice that is designed to provide temporary storage, filtration and infiltration of stormwater runoff. Although the physical design of a bioretention facility can vary, the construction profile generally consists of the following: a gravel storage layer, a choker layer (optional), a bioretention media layer, a mulch layer and a vegetation layers.

A critical component of any bioretention facility is its drainage system. Proper design of the drainage system will depend on the infiltration rate of existing native soils. Sites with highly permeable soils (>15mm/hr) can facilitate bioretention practices that are designed with no underdrain to provide full infiltration. Bioretention facilities designed for sites with less permeable soils (<15mm/hr) will require an underdrain for partial infiltration. In cases where contaminated soils exist or where the water table is high, an impermeable liner and underdrain can be integrated into the bioretention cell to create a facility designed for filtration only. This type of bioretention facility is also known as a biofilter.

When considering an infiltration or partial infiltration bioretention option, practices should be located a minimum of 5 m from the foundation of any building in order to reduce the risk of seepage. Attenuation type biofiltration techniques are suitable within 5 m of a foundation.

Bioretention practices are designed to capture and treat runoff from small storm events. The maximum ponding depth after a storm event should be 150 - 250 mm with larger events handled by an overflow/bypass. Bioretention facilities can also serve as areas for snow storage and snowmelt treatment.

The physical form of bioretention practices can vary to provide a complementary aesthetic within any street type from rural to ultra-urban contexts. Types of bioretention facilities include:

- Bioretention / Stormwater Planters;
- Bioretention Curb Extensions/Bump-outs;
- Bioretention Cells; and,

Photo Credit: Schollen & Company Inc.

3.2.15.1| Bioretention Planters

Bioretention planters are constructed with 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.

They are well-suited for ultra-urban street types and can be adapted to fit within Furnishing Zones and Medians. As a result of their context, bioretention planters require hardy, aesthetically-pleasing plant materials that tolerate harsh urban conditions and winter maintenance protocols.

Bioretention planters are often located in higher pedestrian traffic areas, therefore design solutions should consider planting, curb or railing options that will impede pedestrians from inadvertently stepping into a planter bed.

Stormwater planters are similar to bioretention planters in their form and function, however stormwater planters typically located within the Frontage Zone or directly adjacent to a building. They can be designed to receive runoff from downspouts and surrounding sidewalks.

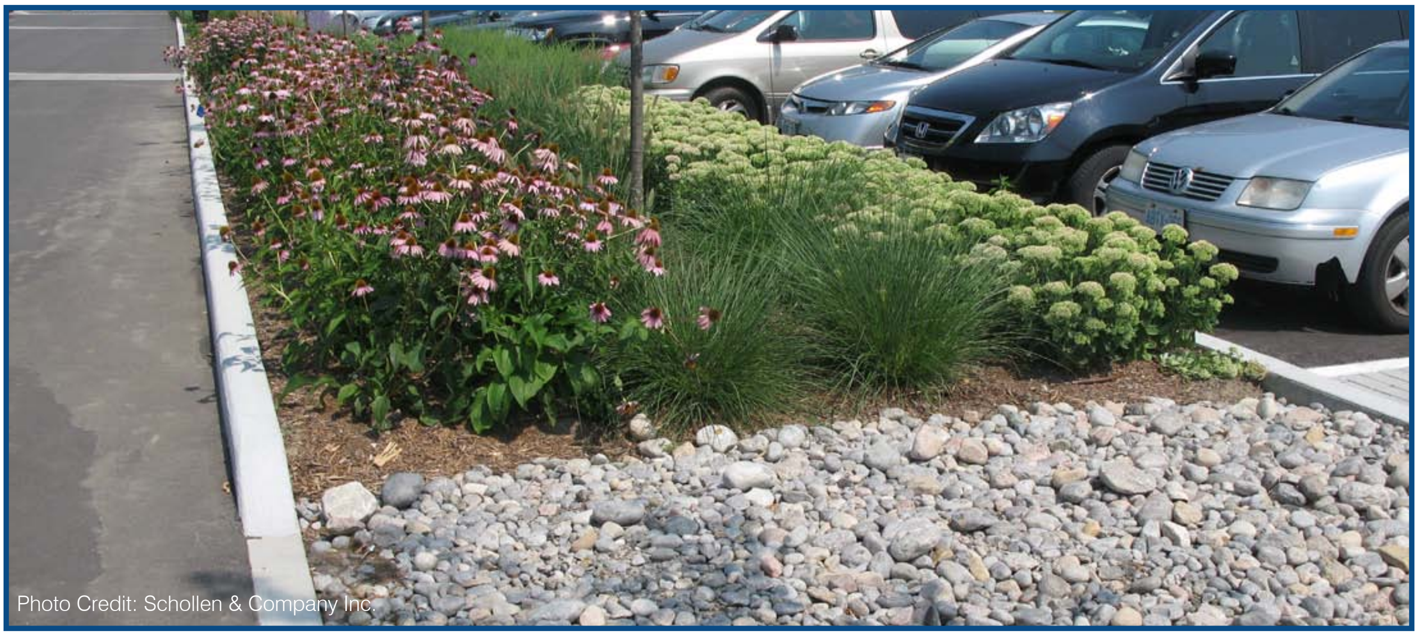


Photo Credit: Schollen & Company Inc.

Extension/Bump-Outs

Curb extensions and bump-outs provide another design variation of 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-section.

Curb extensions / bump-outs are typically on-line stormwater management practices, meaning that they are in the direct flow path of runoff that is conveyed along the curb. This is an important consideration as it affects the pretreatment design and maintenance protocols for these options.

3.2.15.3| 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.

3.2.15.4| 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.

Image Credit: Schollen & Company Inc.

3.2.16| Stormwater Tree Pits

Stormwater tree pits are a variation of the traditional tree pit that receives stormwater runoff from the road through curb inlets. They consist of a tree installed in filter media with an open bottom to promote infiltration into the surrounding native soils.

Stormwater tree pits are well-suited to ultra-urban street types and are typically installed within the Furnishing Zone. Where large mature trees are desired, additional soil volume can be provided using soil cells.

3.2.17| Stormwater Tree Trenches

Stormwater tree trenches consist of a series of stormwater tree planters connected through the underground trench system. The excavated trenches are backfilled with engineered soil. Soil volumes can be further augmented by installing soil cells.

Stormwater tree trenches are well-suited to ultra-urban street types and are typically installed within the Furnishing Zone. Permeable pavement is an optional appropriate surface treatment over a stormwater tree trench as this type of pavement allows for air circulation and water infiltration into the tree trench.

3.2.18| Swales

Swales typically require a large area and are therefore well-suited for installation within Planting Zones and Medians in suburban street cross-sections such as Neighborhood Residential, Connector and Employment streets. They consist of linear vegetated channels that convey, treat and attenuate stormwater runoff. Vegetation and check dams may be integrated into swales to slow the velocity of runoff, allowing for sedimentation, filtration, evapotranspiration and infiltration (depending on soil infiltration rates). Swales also provide a suitable location for snow storage during the winter months.

3.2.18.1| Enhanced Grass Swales

Enhanced grass swales are similar to traditional grass swales, however they feature a slightly altered parabolic form and incorporate amended soils that slow runoff and assist in contaminant removal. Enhanced grass swales can serve as a pretreatment option for infiltration practices, particularly on low traffic volume roadways that do not receive high loads of de-icing compounds in the winter. Check dams can be integrated into the design in order to maximize infiltration benefits.

3.2.18.2| Bioswales

Bioswales are similar to enhanced grass swales in their linear and cross-sectional surface geometry, however their subsurface profile is more reflective of a bioretention cell, with filter media and/or a storage gallery and optional underdrain (depending native soil permeability) below. Bioswales can either be planted with grasses or finished with more elaborate combinations of plant and aggregate materials. These additional components help to slow the velocity of runoff and assist in sedimentation, filtration evapotranspiration and infiltration. As a result of their bioretention profile, bioswales have the potential to be more effective at removing pollutants, reducing runoff and protecting downstream channels from erosion then enhanced grass swales. Bioswales are also referred to as dry swales or infiltration swales.

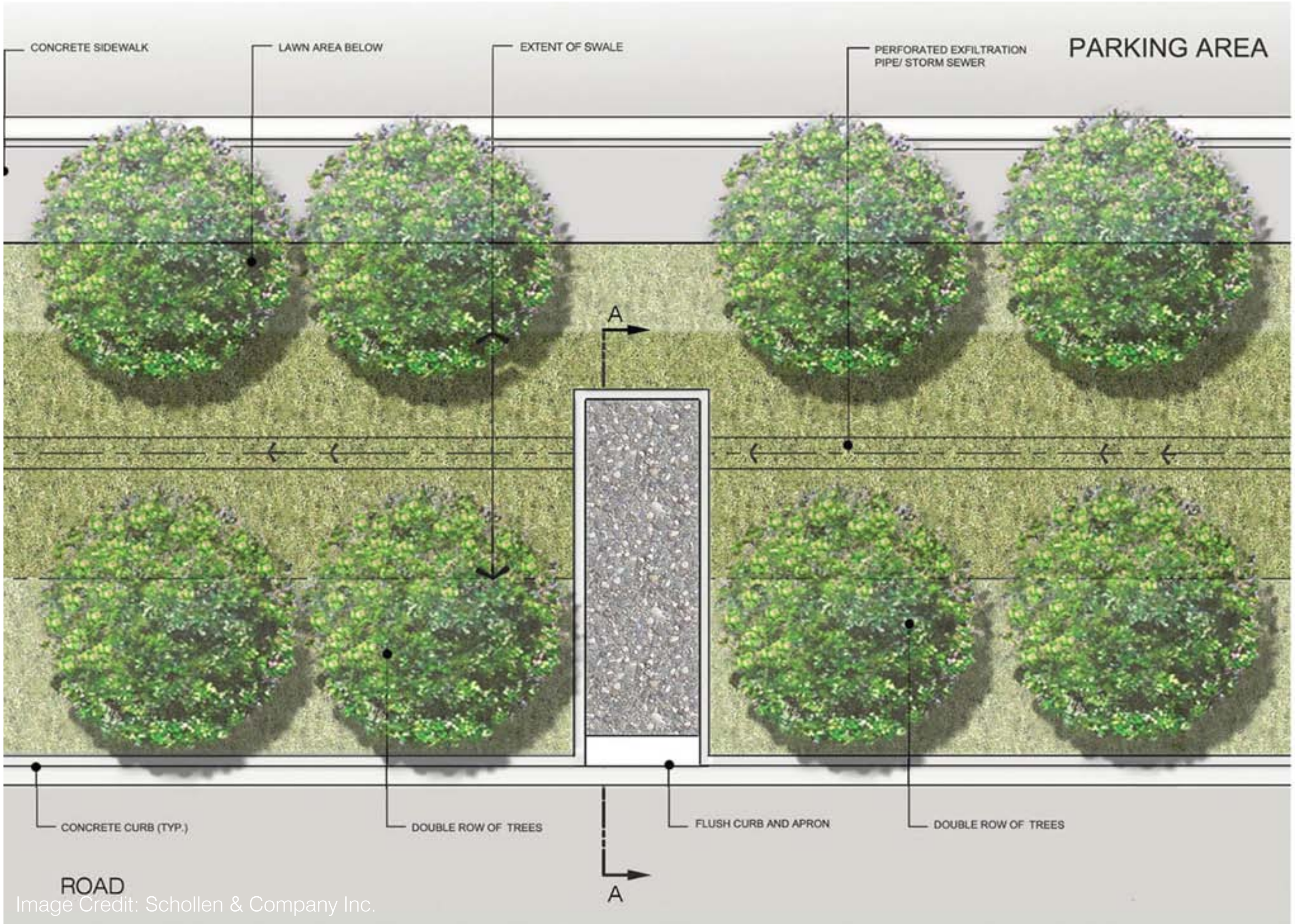


Image Credit: Schollen & Company Inc.

3.2.18.3| Bioswales with Stone Wells

Bioswales with stone wells provide a formal aesthetic that can be integrated into urban street types. They feature the longitudinal surface geometry and sub-surface profile of a bioswale, but also include stone filled wells installed at equidistant spacing along the length of the bioswale to draw stormwater into highly permeable (>15mm/hr) native subsoils more efficiently. This type of bioswale can also be fitted with curb outlets to direct overflows downstream to an existing catch basin. A variation on this design can also include a stormwater inlet at the upstream end that funnels runoff directly to the stone layer of the cell.

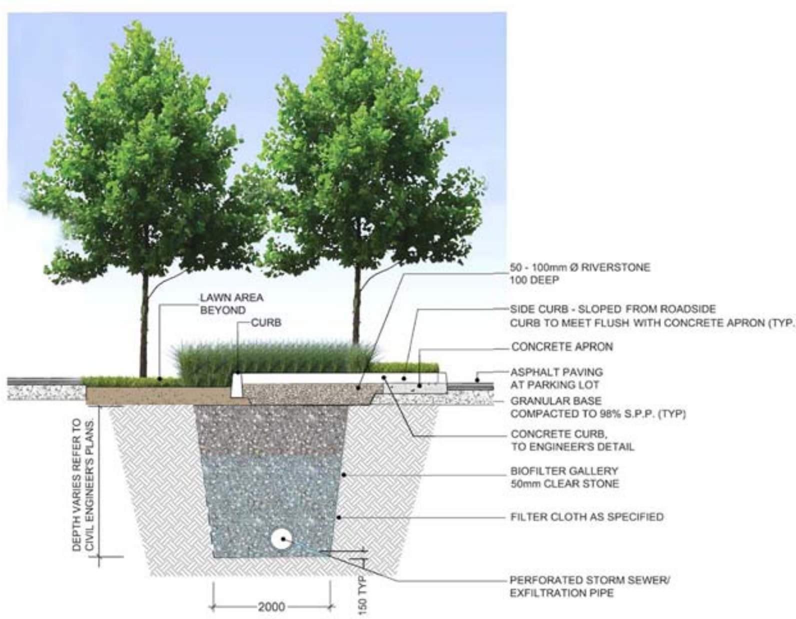


Image Credit: Schollen & Company Inc.

3.2.19| Green Gutters

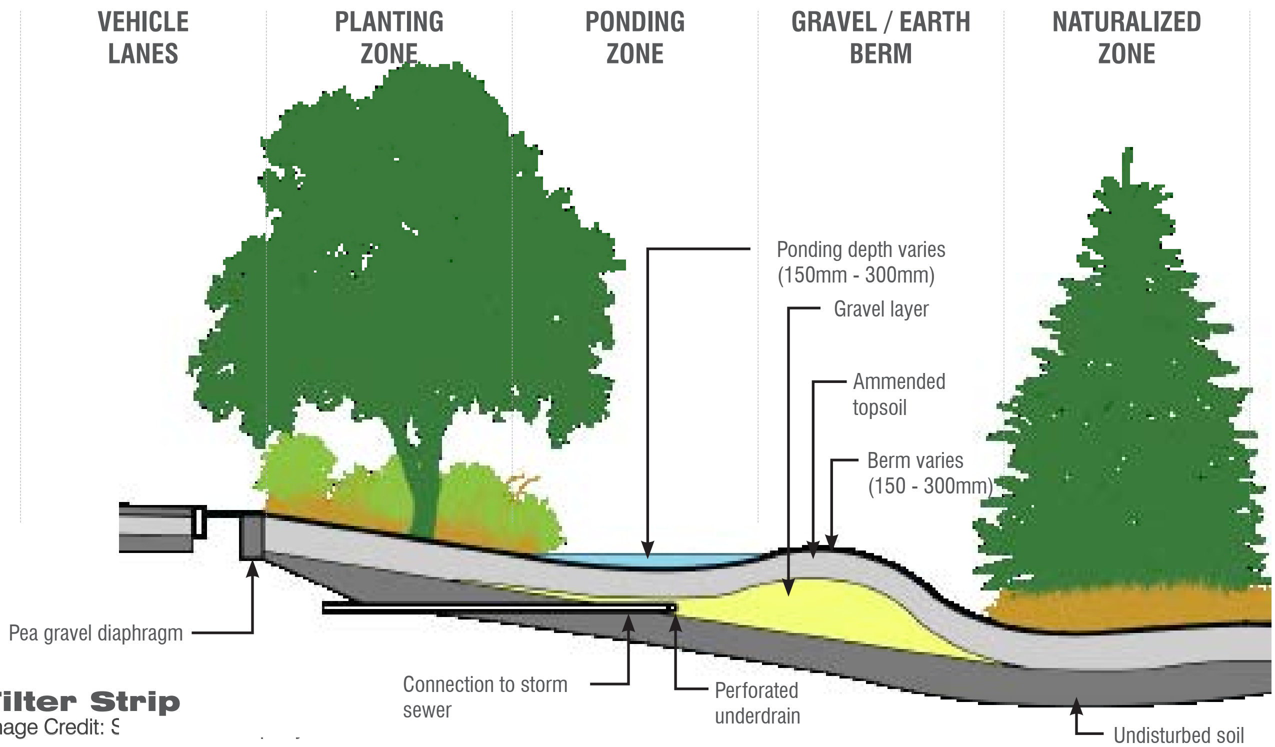
Green gutters are shallow planters that extend the full length of a street section which may incorporate breaks at intervals to accommodate pedestrian movement. Green gutters can be installed as separation between conflicting uses such as between Cycling Infrastructure and Vehicle Lanes within street types where space allows. They can also be installed as GI within dedicated LRT lanes. Green gutters are typically planted with low-growing grasses or sedums and are designed to attenuate, filter and infiltrate stormwater runoff.

Photo Credit: Schollen & Company Inc.

3.2.20| Filter Strips

Filter strips are gently-sloping, heavily-vegetated areas that treat runoff from adjacent impervious surfaces including roadways, sidewalks and driveways. They can be stand-alone stormwater management practices or they can function as pretreatment for other infiltration practices. Filter strips are well-suited to streets with a suburban cross-section or connector streets where no curbs presently exist.

Filter strips should be planted with native material in order to provide maximum ecological and water quality benefits. In the winter months, these areas are well-suited to provide snow storage capacity as they have an excellent capability to filter and infiltrate snow melt in the spring. Filter strips are also referred to as buffer strips.



Filter Strip
Image Credit: S

3.2.21| Underground Infiltration Systems

Underground infiltration systems have little to no surface footprint and can therefore be integrated within the Planting Zone or Vehicle Lanes of almost any street type. The primary function of these systems is to capture, convey (occasionally) and infiltrate stormwater, therefore these systems should only be used in locations with highly permeable (>15mm/hr) native soils. Due to the fact that infiltration is a primary function of underground infiltration systems, care should be taken to avoid contributing drainage areas that may be contaminated or that may receive high volumes of de-icing compounds in the winter. Pretreatment should also be integrated into all systems that receive roadway runoff that may contain large quantities of sediments.

3.2.21.1| Drainage Wells

Drainage wells are vertical perforated pipes that are installed under the surface of a roadway and gradually allow stormwater to discharge into the surrounding native soils. They are connected to inlets along the street and because they treat roadway runoff, a pretreatment system is required. Due to their relatively small surface footprint, drainage wells can easily be implemented throughout a variety of street types including ultra-urban contexts, in both new construction and retrofit scenarios. Care must be taken throughout the design and construction processes to ensure that there are no conflicts with existing utilities in retrofit scenarios.

3.2.21.2| Perforated Pipe Systems

Perforated pipe systems are connected to catch basins installed within the Edge or Planting Zone. This type of system receives runoff from sidewalks, driveways and roadways. The system itself consists of perforated pipes that are installed horizontally along a gradually sloping subsurface trench that is filled with granular and wrapped in geotextile fabric. They can be used in place of, or as a complement to, conventional pipe systems. Due to their relatively small surface footprint, perforated pipe systems can be implemented in almost any street type. However, because of the many constraints inherent to the retrofit scenario, perforated pipe systems are ideally-suited to new construction projects.

3.2.21.3| Soakaways

Soakaways are rectangular excavations, lined with geotextile and filled with clear stone created under a hard or a soft landscape area. They attenuate and infiltrate runoff from sidewalks and other paved surfaces and are ideally-suited for application within the Planting Zones of residential streets or under low volume vehicle lanes (i.e. multi-use or residential lanes). Soakaways are also referred to as infiltration galleries, dry wells or soakaway pits

3.2.21.4| Infiltration Trenches

Infiltration trenches are a design variation of a soakaway that consists of a linear trench lined with geotextile fabric and filled with clear granular stone. Infiltration trenches are well-suited for areas where space is limited to a narrow strip including Medians, Planting Zones or low volume Vehicle Lanes. They can be covered with stone, vegetation or paving depending on context. Infiltration trenches are also referred to as linear infiltration galleries or linear soakaways.


Photo Credit: Schollen & Company Inc.

3.2.21.5| Infiltration Chambers

Infiltration chambers are another design variation on soakaways that incorporate prefabricated modular chambers that are installed under Medians, Planting Zones or low volume Vehicle Lanes to store runoff temporarily before infiltrating it into the underlying native soils. The chambers typically have an open bottom and perforated side walls and are usually placed over a stone reservoir. They can be installed individually or in series depending on available space. Infiltration chambers are well-suited to new construction scenarios, but can also be integrated into retrofit projects with careful planning. Infiltration chambers


Photo Credit: Schollen & Company Inc.

3.2.22| Rainwater Cisterns

Rainwater cisterns intercept, convey and store rainfall for future use. Within the right-of-way there are opportunities to capture runoff in prefabricated cisterns below grade and then to reuse rainwater for irrigation and maintenance purposes. This type of system can be effective in reducing demands on the municipal potable water system.