Low Impact Development Road Retrofits:

Optimizing Your Infrastructure Assets through Low Impact Development

Road Right-of-Way

CREDIT VALLEY CONSERVATION

Welcome to the Credit Valley Conservation Be A Leader Grey to Green Series

As the Chair of Credit Valley Conservation, and City Councillor for Mississauga, I have first hand experience with pressures our communities face with aging infrastructure, changing climate, a growing population, and fiscal crisis. It's growing more difficult to find the resources to meet growing needs.

Municipal infrastructure is regularly overwhelmed and ineffective. Time and time again—especially this past summer—we're reminded that existing systems cannot manage intense storms and are failing to protect the environment.

But there is a solution, and it's not as expensive as you might think. In fact, the low impact development (LID) approach easily ties into existing systems, our public lands, road right-of-ways, commercial and institutional properties and residential homes all present opportunities. Properly maintained LID features promise a quick return on investment and many other benefits. With LID, you can:

- **Protect assets and defer larger investments.** LID barriers can slow the flow to storm sewers during intense rain events, giving them more time to process stormwater. In this way, LID helps meet asset management requirements, reduces damage to existing systems, and extends the useful life of infrastructure.
- **Save money. Smaller, more frequent events cause costly damage.** LID practices encourage infiltration and can help reduce the amount of erosion, and pollutants to creeks, rivers, and streams that leads to regular and often expensive maintenance and lost revenues from beach closures.
- **Increase tax revenue.** Free space in growing cities is at a premium. The cost of land can be as much as four times the cost of new infrastructure. LID practices require minimal land expropriation, and often fit into existing urban infrastructure, leaving more land available for development and tax revenue.
- **Build resiliency and protect the environment.** One technology alone isn't enough to ensure resiliency. Adding LID measures to a treatment train can reduce the frequency of flood-related residential damage due to overwhelmed existing systems. LID can also reduce the flow of contaminated stormwater to surface waters, which can harm aquatic environments, and increase the cost of treatment at the drinking water level.

If you see opportunities for LID in your municipality, we encourage you to review the business case (Chapter 1) and pass along this user-friendly guide to your clients, municipality's staff, property managers, land developers and infrastructure teams.

On behalf of all of us at Credit Valley Conservation, we hope this Guide can help create vibrant, healthy, sustainable communities!

Pat Mullin

Councillor, City of Mississauga and Region of Peel
Chair, Credit Valley Conservation

P.S. This guide is a living document. We invite you to share your experiences with LID for future editions, and reach out to the CVC team for further guidance and collaboration. Please visit our website for access to all the Grey to Green guides: http://www.creditvalleyca.ca/low-impact-development/low-impact-development-support/stormwatermanagement-lid-guidance-documents/

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Welcome to the Grey to Green Road Right-of-Way Retrofit Guide

LID

low impact development is a green infrastructure approach to stormwater management that uses simple cost-effective landscaped features and other techniques to filter, store, infiltrate and use rainfall where it falls.

Who should read this guide?

The Grey to Green Road Right of Way Retrofit Guide supports municipalities retrofit their road right of ways (ROWs) with innovative LID practices. The information in this guide is aimed at the following audience:

- Municipal planners, engineers and technical staff
- Engineering consultants and landscape architects
- Contractors

More broadly, readers can include anyone involved in funding and making decisions about municipal infrastructure and stormwater management including councillors, commissioners and the public.

Why should I read this guide?

In a time of increasing population growth and density, fiscal constraints, aging infrastructure, and unpredictable weather, municipalities must maintain a level of service that meets federal and provincial policies and legislation, as well as meet their own guiding documents and policies. This can be a real challenge. This guide's aim is to offer advice and support—both political and technical—for the adoption of LID within road infrastructure in order to maintain and enhance a municipality's level of service.

How will this guide help me?

This guide presents the business case for LID as well as in-depth guidance, tools and case studies to make LID a mainstream practice for municipalities of all sizes. This guide will help you:

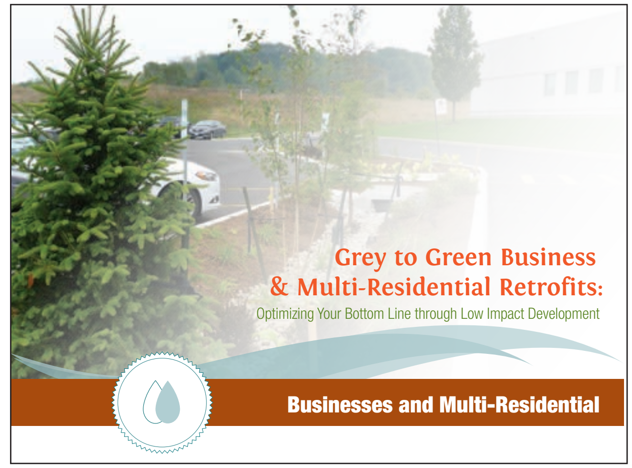
- Understand the long-term cost savings of LID and how to finance retrofits using innovative financial tools such as Gas Tax funding
- Figure out which LID options are best suited for your road right of ways based on road type and scale of construction project
- Assemble the project team and foster effective consultation with the public
- Ensure long-term success by giving you the tools to properly build and maintain your LID project over its lifetime

Where should I go for more information?

For more information on the design, construction and lifecycle activities of LID features and case studies on road ROW retrofits please visit Credit Valley Conservation's (CVC) Be a Leader website at

bealeader.ca

Check out the entire suite of the Grey to Green Retrofit Guides:



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1.0 The Business Case for Grey to Green Road Retrofits

(Source: Fred Loek, Mississauga News)

1.1 Municipal stormwater challenges

The following section provides context for building the business case for LID road retrofits from a municipal and provincial perspective.

Challenges municipalities face with managing their infrastructure assets

Municipalities have long identified the need to upgrade stormwater management to protect our Great Lakes and build resiliency in the face of extreme weather events. For instance, the Great Lakes Cities Initiative has identified stormwater as a priority for protecting the Great Lakes[1] and the Region of Peel's Climate Change Strategy lists stormwater as one of its top priorities[2].

Figure 1.1.1: July 8, 2013 flooding also impacted private property. In this photograph a Mississauga resident shows the structural damage that took place to her home. (Source: Fred Loek, Mississauga News)

On July 8, 2013 one rain guage located in Mississauga recorded 100 mm of precipitation over a five hour period, with a 240 mm/h peak intensity over a 10 minute interval. LID practices installed at a demonstration site on Elm Drive in Mississauga were found to provide 60% peak and 30% volume reductions as well as a 20 minute lag time for discharge to leave the site.

With the 2013 floods in southern Alberta and the Greater Toronto Area, attention is shifting to Canada's aging infrastructure, which is in need of rapid repair and replacement with a total cost mounting to $170 billion[3] for water supply, wastewater, stormwater and road infrastructure stock. Ontario accounts for almost 60% of that, needing to replace existing water supply, wastewater, stormwater and road infrastructure stock (of which stormwater represents 23%). This estimate does not take into consideration the need for new infrastructure within existing urban areas not currently receiving flood control or water quality treatment. For example, it is estimated that only 35% of the greater Toronto area (GTA) has stormwater quality treatment. To bring older developments across the nation to today's standards, it is estimated to cost an additional $56.6 billion[4]. This figure assumes conventional practices are feasible and does not include land acquisition costs, which in growth areas around Toronto can be 3-4 times that of infrastructure costs[5].

These recent extreme events can cost insurers and governments billions. More frequent storm events can also cause property damage in older areas without an overland flow route or stormwater management. This can cause lost revenue for businesses in impacted areas. Impacts to Lake Ontario through combined sewer overflow (CSO) discharge, spills and non-treated stormwater discharge. As roads have been found to produce as much as 80% pollutant loading in urban areas[6]; incorporating LID within road reconstruction projects has both cost and environmental benefits.

Due to pressures of growth and limited funding, municipalities are facing challenges as many water supply, wastewater, and stormwater infrastructure systems approach the end of their planned service life. Municipal infrastructure requires major economic investment for rehabilitation or replacement.

Municipalities in Ontario are responsible for more than 15,000 bridges and culverts and more than 140,000 km of roads[7]. For every tax dollar collected, municipal governments are given eight cents[8]. With that funding, they must deliver a host of services. This makes it increasingly important that financial resources be spent on coordinated solutions to maximize service delivery.

> Modern and reliable infrastructure drives our economy. It contributes to our province's wealth and productivity, and it helps us attract investment and create jobs.
>
> – Ontario Ministry of Infrastructure[9]

LID is also not just a big city solution. In municipalities who rely on groundwater supply, increasing urbanization and the associated increase in water takings and impervious cover can impact water supply and baseflow. The Tier 3 Source Protection (SP) study for Orangeville, Mono and Amaranth found that baseflow in headwater streams could be reduced by as much as 23% if only conventional stormwater management is adopted for new developments[10]. Modelling results from the Credit River Headwater Subwatershed Study found that an uptake rate of 20% LID within existing urban areas (outside wellhead protection areas) and 100% adoption within new developments (outside of wellhead protection areas) will help to maintain baseflows the water supply that provides assimilative capacity for Orangeville's Waste Water Treatment Plant[11].

Meeting provincial and federal legislation, policies, and objectives

In Ontario, LID offers a means to assist municipalities meet a wide variety of objectives, goals and priorities, particularly those relating to sustainability. To this end, the Province has recently developed a suite of legislation, policies, and incentives designed to promote LID and other best practices. Some specific examples:

- Under the Water Opportunities and Water Conservation Act (2010), municipalities will be required to develop sustainable water, stormwater, and wastewater plans. These plans may include a water conservation plan, an assessment of risks to the future delivery of municipal services from climate change, and consideration of technologies, services, and practices that promote the efficient use of water while reducing negative impacts to Ontario's water resources.

- The Great Lakes Protection Strategy (2012) guides efforts to protect the Great Lakes and Ontario's role in the Canada-Ontario Agreement Respecting the Great Lakes Basin Ecosystem. The strategy strongly supports green infrastructure, low impact development, and stormwater management.

- Climate Ready: Ontario's Adaptation Strategy and Action Plan identifies a need for increased resilience of municipal stormwater systems in light of climate-change induced alterations to rainfall intensities and storm patterns.

- Places to Grow encourages municipalities to implement and support innovative stormwater management actions as part of redevelopment and intensification.

- The Provincial Policy Statement (PPS) (2012), includes new policies for planning for stormwater management. As well, a new policy (1.6.2) encourages green infrastructure approaches. These new policies will encourage consideration of low impact development earlier in land use planning decisions.

- In 2011, the Ministry of Municipal Affairs (MMAH) released its Municipal Planning and Financial Tools for Economic Development handbook, which provides descriptions of planning and financial tools for municipal economic development goals. The handbook's Sustainability Connection checklist for land-use planning identifies groundwater recharge, reduced stormwater runoff, and water recovery. MMAH also highlights LID as an element of site plan control in Key Planning Act Tools to Support Climate Change Action.

- The Ministry of Infrastructure's plan, Building Together: Jobs and Prosperity for all Ontarians, recognizes the impact climate change will have on stormwater infrastructure and cites the need to reduce water demand through promotion of conservation and use of green infrastructure.

- Other provincial initiatives have implications for municipalities, and LID can help meet those requirements. Some examples include the Lake Simcoe Protection Plan, the Ontario Building Code, and the Modernization of Approvals initiative within the environmental registry system.

- Ontario's Ministry of Infrastructure (MOI) has launched an infrastructure strategy that requires municipalities seeking capital funding to create long-term asset management plans. Many principles guide this strategy, including the need for plans to guide investment decisions. Building Together: Guide for Municipal Asset Management Plans outlines some of the required content for asset management plan submissions to the Province.

For information on how LID can help you meet municipal objectives, refer to Appendix A and for information on how LID can help you meet Provinicial Asset Management requirements, refer to Appendix B.

Paving the way for LID

On March 5, 2014 Mississauga Council adopted Resolution 0046-2014 that recognized the contributions of LID towards meeting the City's Living Green Master Plan and Strategic Plan. The resolution directed the Transportation and Works Department to report on the technical and cost feasibility of LID opportunities associated with the road capital programs for the following year.

Figure 1.1.3: Honourable Jim Bradley, former Minister of the Environment speaking at a groundbreaking event at the IMAX parking lot LID retrofit groundbreaking event. (Source: CVC)

1.2 The business case for LID

When focusing on individual budget line items for capital projects, such as the comparatively higher cost of pervious concrete over traditional pavement, one tends to assume that LID increases project costs.

Of the $170-billion national municipal deficit for water supply, wastewater, stormwater and roads, stormwater and roads comprise 23% and 53%, respectively[12].

Looking at broader goals, such as the Province's asset management requirements and community development, however, shows how the perceived higher costs of green infrastructure/LID actually lead to long-term savings and benefits. From a lifecycle perspective, LID can reduce development costs because it can reduce the need for conventional infrastructure, such as curbing, piping, ponds, and catch basins[13].

How else does green infrastructure support our environment, economy, and society? We've designed this brief business case to help you determine how LID can meet needs and provide additional benefits to your municipality.

The direct and indirect savings of implementing LID in road right of ways relate to three main lifecycle phases: construction, operation and maintenance and rehabilitation and disposal. The following sections discuss these in greater detail.

Did you know that you can use the Federal Gas Tax Fund to finance LID road retrofit projects in your municipality? The City of Brampton is using the Gas Tax Fund to implement bioswales on County Court Boulevard as part of a sustainable neighbourhood retrofit project. Check out Section 1.4 for more details.

Construction savings

Where LID is included in the street cross-section, municipalities generally find savings with reduced direct infrastructure costs and reduced lifecycle costs, since there are fewer pipes, fewer below-ground infrastructure requirements, and more pervious area. This was considered by the City of Ottawa in their Green Municipal Fund Grant Application[14].

The capital costs for GSPP [grass swale perforated pipe] drainage systems, while greater than those incurred by leaving the open roadside ditch in place, are less than installing the full urban road cross-section.

- City of Ottawa
Green Municipal Fund
Grant Application[15]

The City of Seattle reported a savings of 10-20% over traditional street developments that typically incorporate curb, gutter, catch basins, asphalt, and sidewalks[16]. Savings will continue as costs for LID technologies such as permeable pavement and bioretention soil decrease with demand. For example, in 2005, the City of Chicago paid about $145 (USD) per cubic yard of permeable concrete and in one year the cost dropped to only $45 per cubic yard[17].

A 2007 U.S. EPA study of 17 greenfield and redevelopment case studies from the United States and Canada compared the construction costs of LID versus conventional design[18]. On average, the EPA study found that LID reduced construction costs by 25%[19]. Table 1.2.1 provides a summary of select ROW case studies from the study, including some additional case studies from Canada and the United States.

Table 1.2.1: Summary of construction cost comparison for selected LID case studies[20,21,22,23,24]

Project	Project Type	Road Length	LID Practice	Construction Costs			Cost savings
				Conventional design	LID	Cost difference	
Lakeview Project, Mississauga, ON	ROW Retrofit	285 m	• Bioretention • Permeable pavers	$1,090,000*	$895,000	$195,000	18%
Elm Drive Project, Mississauga, ON	ROW Retrofit	210 m	• Bioretention • Permeable pavers	$650,000	$585,000	$65,000	10%
Hogg's Hollow Project, Toronto, ON	ROW Retrofit	267 m	• Perforated pipe	$646,000	$719,000	-$73,000	-11%
Crown Streets, BC	ROW Retrofit	335 m	• Bioretention • Vegetative lanscaping	$364,000	$396,000	$-32,000	-9%
Boulder Hills - Roadway, sidewalk & driveway, NH	New ROW	275 m	• Permeable asphalt	$4,389,000	$4,340,000	$49,000	1%
2nd Avenue, SEA Street Retrofit, Seattle, WA	ROW Retrofit	200 m	• Bioretention • Reduced impervious area • Swale	$869,000	$652,000	$217,000	25%

* Assumes construction of end-of-pipe facility to provide equivalent level of stormwater treatment

In some cases, LID may seem to have higher construction costs than conventional road reconstruction projects. When comparing LID to a conventional roads project, however, it is important to consider the long-term economic, environmental and social benefits of implementing LID as well as the corresponding risks of not implementing LID. For instance, upgrading an older local residential road from a rural cross section (ditches) to modern curb and gutter may have a lower construction cost compared with an LID retrofit, but will provide none of the stormwater quantity control and quality treatment benefits provided by LID. If a municipality wanted to provide these same benefits using conventional practices like a stormwater management pond, land would need to be set aside or appropriated at significant expense. This is one of the major advantages of LID in that it provides municipalities with a tool to retrofit these existing areas, where conventional approaches would likely be cost prohibitive.

An example of the costs, benefits and risks associated with a road reconstruction project upgrading a road from ditches to curb and gutter is provided in Figure 1.2.1. This figure was developed using as-constructed costs associated with an LID demonstration project located in the Lakeview neighbourhood in Mississauga. Figure 1.2.1 compares these costs to those associated with a traditional road reconstruction and reconstructing the road while providing similar levels of stormwater control via an end-of-pipe pond.

For further details on the Lakeview project, refer to the case study in Appendix C.

Cost Benefit Comparison

Direct Benefit Rating: ● High ◉ Moderate ○ Low ⦸ None

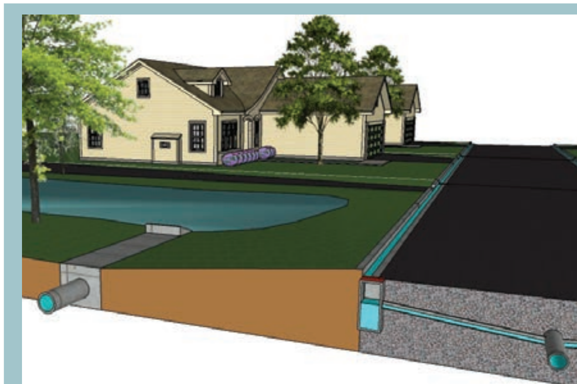
Boulevard bioretention units and permeable paver driveway:

Direct benefits:
- ● Volume reduction
- ● Erosion control
- ● Water quality
- ○ Flood control

Indirect benefits:
- ✔ Climate change mitigation & adaptation
- ✔ Protect Great Lakes
- ✔ Increase amenity value
- ✔ Street greening
- ✔ Groundwater recharge
- ✔ Improve baseflow
- ✔ Helps to meet or exceed environmental strategic plan objectives

Municipal Considerations:
- ✕ Impaired function from owner encroachment or lack of maintenance
- ✕ Long-term soil replacement

Best value $895,000



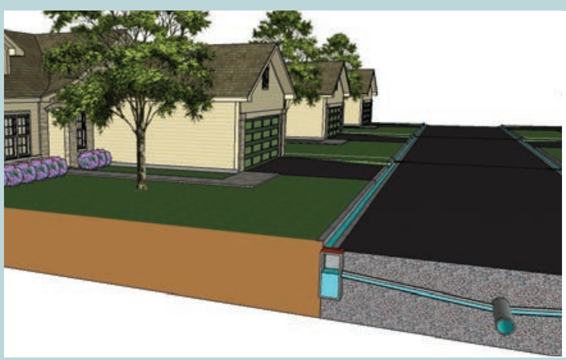
Curb-and-gutter with stormwater management pond:

Direct benefits:
- ○ Volume reduction
- ◉ Erosion control
- ◉ Water quality
- ● Flood control

Indirect benefits:
- ✔ Maintains traditional road aesthetic
- ✔ Protect Great Lakes
- ✔ Help meet environmental strategic plan objectives
- ✔ Open space amenity

Municipal Considerations:
- ✕ Higher maintenance costs
- ✕ No groundwater recharge
- ✕ Increased erosion control costs
- ✕ Pond sediment clean out

High cost, moderate benefits $1,090,000



Conventional road reconstruction (curb-and-gutter):

Direct benefits:
- ⦸ Volume reduction
- ⦸ Erosion control
- ⦸ Water quality
- ⦸ Flood control

Indirect benefits:
- ✔ Maintains traditional road aesthetic

Municipal Considerations:
- ✕ Downstream flood risk
- ✕ Harm to fisheries
- ✕ Increased erosion control costs
- ✕ No groundwater recharge
- ✕ Impaired water quality
- ✕ Beach closures

Lowest cost, few benefits $635,000

Figure 1.2.1: Comparison of road retrofit alternatives for a local residential road converting from a rural cross section to an urban cross section

Operation and maintenance savings

Municipalities concerned that LID results in increased maintenance costs need only consider the large-scale and complex rehabilitation activities required for conventional stormwater management ponds to realize how LID will save money.

To maintain design depths, stormwater management ponds require sediment removal, which is typically the responsibility of the municipality. Since many Ontario municipalities have not yet planned or executed these activities, the life-cycle costs of maintaining these ponds are largely unknown. However, there is a growing concern that dredging and disposal will be costly, particularly if the sediment is contaminated and requires specialized disposal[25].

Proper maintenance of these ponds and the entire stormwater management infrastructure is critical for ensuring the safe and effective management of stormwater. It is also a critical component for reducing a municipality's liability and risk associated with protecting against injury caused by climate impacts like flooding. As municipalities have jurisdiction for overseeing water management systems, it is important that they demonstrate a standard of care that includes ongoing activities like regular inspection, maintenance, repair and replacement when needed.

Maintenance of ponds also plays a crucial role in meeting the Ministry of the Environment and Climate Change's (MOE's) Environmental Compliance Approval (ECA) permits. A recent Lake Simcoe Region Conservation Authority (LSRCA) study found the effluent water quality of wet ponds deteriorates over time due to sediment accumulation and other chemical processes within the pond so that wet ponds can become sources of phosphorus to receiving water bodies if not properly maintained[26]. In general, reduction of the wet storage area in wet ponds due to sediment accumulation tends to reduce the water quality and quantity control capacity of the facility and increases flood risk[27].

For further information on the potential risks and liabilities associated with stormwater management refer to Appendix D.

LSRCA found that the costs for pond maintenance can range from $267,000 up to $1.6 million. In comparison, the Toronto Region and Conservation Authority (TRCA) found that maintenance costs for LID within road right of ways varied from an average of $732/100m^2 per year for bioretention to $1,255/100m^2 per year for infiltration trenches and chambers over the life of the practices (50 years). That being said, LID projects typically require regular maintenance, especially in the early stages of establishment in order to ensure vegetation success. However, once established, LID projects can often be maintained in the same manner as landscaping elements requiring mowing, weeding, and debris removal on a semi-frequent basis. Figure 1.2.2 presents the life-cycle maintenance costs used in the report.

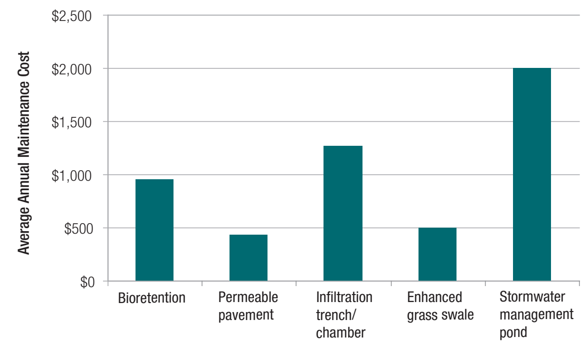


Figure 1.2.2: Life-cycle maintenance costs for LID practices and conventional stormwater management pond[28,29]

LID benefits from the combination of public and private responsibilities. Studies in the United States and Canada have found that landscape design plays a critical role in private landowners maintaining LID features[30,31] and can encourage adoption and ownership of project maintenance by a homeowner. The Lakeview Project in the City of Mississauga has revealed that residents are interested in being involved and taking responsibility when LID is incorporated in to the ROW. This is in part because residents were engaged from the beginning as the City and CVC used market research to engage residents through open houses, BBQs, and developing landscape design options. As a result, the residents have not only cleaned debris and watered the plants, but have added plants to both their property and the bioretention cells.

To some people this finding may not be a surprise. In most municipalities, residents are required to maintain the ROW, mowing grass regularly and watering when needed. If a municipality is concerned that residents would not maintain plants, sod is an alternative that does not require the same level of service. In the case of retrofits, the municipality and designer have the luxury of engaging the community and seeing how the neighbourhood uses the land before selecting LID techniques or landscape options, see Chapter 3 – Building the Project Team & Consulting the Public for further details on this topic.

Lakeview is not an exception. In projects throughout the United States, many municipalities have also claimed local residents take ownership of LID features in the ROW, seeing it as a community amenity and feature that beautifies the neighbourhood. Residents have claimed these features strengthen communities, especially as residents work together to maintain the features. This has also been found to be true in Lakeview, as residents outside of the demonstration site are requesting LID within their ROW.

Stormwater rates support municipalities through the creation of a dedicated pool of funding that can be devoted to conducting LID maintenance on city property and enforcing LID maintenance on private property. In the United States many municipalities have begun to adopt such a rate system. In Canada, municipalities have been slower to adopt this approach but Kitchener and Waterloo are Ontario examples. Refer to the Stormwater Rate Case Study on CVC's Be a Leader website for an overview of municipalities implementing stormwater management rates.

Figure 1.2.3: Many residents in the Lakeview neighbourhood in Mississauga have taken ownership of the boulevard bioretention gardens that were installed in front of their homes, performing regular maintenance and supplementing it with their own plants. (Source: CVC)

Portland, Oregon encourages community involvement in maintaining LID practices through a program recognizing residents as Green Street Stewards[32]. Residents clear debris and water plants during droughts. These activities have resulted in residents' recognition of the value of stormwater and have reduced the burden of maintenance for the municipality. In the Silver Lake Neighbourhood development in Massachusetts, rain gardens in the ROW extend to the front yards of many of the homes. Upon visiting the site four years after residents had moved in, the gardens appeared well-maintained[33].

Case Study: Lakeview

LID Features:

- **Bioretention**
- **Permeable pavement**

In 2012, the City of Mississauga partnered with Credit Valley Conservation to implement one of Ontario's first residential green street retrofits in the Lakeview neighbourhood, replacing older roadside ditches with LID features in the road ROW. The demonstration project was aimed at improving drainage within the ROW, adding modern stormwater controls to an older neighbourhood and enhancing street aesthetics.

Residents on the retrofitted streets received a number of benefits, including:

Improved aesthetics – existing roadside ditches were replaced with boulevard bioretention features, addressing the issues of debris accumulation and ponding water associated with the old ditches. Residents were given the option of selecting either a landscaped feature with plants or a sod option.

The City of Mississauga also benefits from this road retrofit project through:

Retrofitting older neighbourhood – the City was able to retrofit an area built before the introduction of modern stormwater controls. Stormwater runoff is now treated before being discharged to Lake Ontario. 29 mm of rainfall is retained onsite with a corresponding total suspended solids (TSS) loading reduction of 89%[34].

Alternative to traditional curb and gutter – the City of Mississauga is able to use this project to demonstrate an alternative to traditional curb and gutter and evaluate the performance of LID infrastructure within a residential ROW setting.

(Source: CVC)

For more information, check out the Lakeview case study in Appendix C

Rehabilitation and disposal savings

While municipalities often consider initial costs, many do not consider the costs related to the rehabilitation and disposal. Underground stormwater infrastructure requires ongoing repair, rehabilitation and eventual replacement and stormwater pond rehabilitation is costly and cumbersome.

Municipalities have conducted long-term performance monitoring at many of Ontario's LID sites, some of which have been operational for more than 15 years. These studies have found that many LID practices can operate for extended periods of time and with very little maintenance. Examples such as the perforated pipe systems in Ottawa and Etobicoke demonstrate that LID systems are resilient and can potentially have lower rehabilitation costs[35,36].

In accordance with their ECA requirements, the City of Brampton requires sediment removal on a 10-year cycle. To date, the city has performed minor maintenance on 143 ponds[37]. In 2012 the city scheduled the rehabilitation of four ponds, which involved the removal of sediment to reinstate functionality, at a cost of $2 million[38]. The scope of this work includes site preparation, fish and wildlife rescue by qualified personnel, clearing and grubbing, siltation control, removal of sediment, dewatering, hauling and disposing the sediment to an appropriate facility, and pond restoration and naturalization[39].

At one Ottawa-based site, studies conducted on a grass swale and perforated pipe drainage system found that they continued to function effectively even after 20 years of service with very little maintenance[40]. Video inspections of the perforated pipe found little deterioration, sediment accumulation or any other issue that would impair system performance. Tests found runoff volumes were 73-86% lower than in conventional systems. The lower volumes resulted in a TSS reduction of 81-95%[41].

1.3 Additional benefits to consider

There are many more benefits associated with implementing LID beyond those highlighted in this chapter. Some of the benefits include:

Reduced flood risk

Water-related damages have grown over the last nine years and now accounts for 50% of property-related insurance claims in Canada[42].In the aftermath of extreme events like that of July 8, 2013, in which over 100 mm fell over a 5 hour period across the GTA, it is easy to overlook the fact that in older developments, frequent, smaller events can also cause damage to property and infrastructure. LID practices have been found to attenuate peak flow rates and decrease the volume of urban stormwater conveyed to municipal storm sewers.

There are performance studies that have measured the benefits of sites constructed with LID versus conventional stormwater management. These studies commonly find that LID development reduces the frequency of discharge, runoff volume and peak flows for most storms which, in turn, greatly reduces the erosion potential and pollutant loading of the runoff. Some statistics include:

- **Mississauga, Ontario -** The Lakeview neighbourhood project retains 29 mm of rainfall[43]. The Elm Drive ROW retrofit project infiltrates rainfall events up to 25 mm and during the July 8, 2013 storm the site provided a 20 minute lag time of of outflow from the site.[44]
- **Etobicoke, Ontario -** A perforated pipe exfiltration system on a low density residential street infiltrates all events less than 15 mm[45]
- **Montreal, Quebec -** No outflows for all 204 events at one site, up to an including a rainfall of 37 mm[46]
- **Cross Plains, Wisconsin -** LID site released total discharge volumes of roughly one-tenth that of the conventional basin[47]
- **Jordan Cove, Connecticut -** LID approach decreased runoff volumes for all storms by an average of 74% and demonstrated the ability to reduce peak discharges by approximately 27%[48]

Reduced risk of erosion

In-stream monitoring in one of CVC's urbanizing subwatersheds has found that despite conventional stormwater management ponds, increases in wet weather stream flow can be as much as ten times that of pre-development. This is largely due to the fact that ponds do not provide volume control. Increased flow exacerbates erosion in receiving watercourses and this can lead to channel instability, downstream hazards (increasing bank erosion and channel migration), increased costs to the municipality for erosion protection maintenance and responding to property owner complaints.

LID practices such as bioretention and permeable pavement are designed to mimic pre-development hydrology and runoff volume reducing the demand on conventional stormwater controls, and providing effective erosion control[49]. As noted above, on-going monitoring at Elm and Lakeview in Mississauga Ontario has determined that these sites are able to infiltrate up to a 29 mm storm event. These findings show that Ontario-based LIDs perform to the same level as many LID practices in cold weather regions in the United States, whose performance data has been posted to the International Stormwater Best Management Practices (BMP) database.

Water quality compliance

While roadways make up a small component of urban areas, they have proven to be a significant contributor of urban pollutants[50]. LID offers improved water quality in terms of pollutant removal and reduced nutrient loading through a planned approach to grading, the use of plants, natural features, filtration, and distributed infiltration techniques to accept stormwater flows. Long-term data from the University of New Hampshire Stormwater Center (UNHSC) and Villanova University in Pennsylvania found mature bioretention facilities providing 97% TSS removal[51,52].

A number of studies on the treatment effectiveness of LID practices in a Canadian context are currently underway by several conservation authorities, including CVC, TRCA, and LSRCA. One of the first comprehensive studies in Canada, conducted by the TRCA, compared the runoff from an asphalt parking lot to the stormwater infiltrated in a permeable pavement lot and a bioswale. The study found that concentrations of zinc, phosphorus, TSS and oil and grease were significantly lower in the permeable paver infiltrate than the asphalt lot runoff[53].

Results from CVC's infrastructure performance and risk assessment (IPRA) being conducted at the Elm Drive retrofit project show significant reductions in pollutant loads. Elm is able to infiltrate large events, meaning very little leaves the site. When accounting for this volume reduction, contaminant loading reduced considerably. 85% of TSS is removed which greatly exceeds the MOE enhanced treatment requirements of 80% removal[54]. The TSS concentration is also below Provincial Water Quality Objectives, indicating that discharge from this site does not negatively impact the receiving aquatic environment.

Figure 1.3.1: LID infrastructure performance assessment conducted by CVC and its partners is finding significant gains in water quality with LID. This photograph shows a sample collected from a typical curb-and-gutter road (left) compared to runoff treated by a bioretention LID practice (right). (Source: CVC)

Case Study: Elm Drive

LID Features:

- **Bioretention planters**
- **Permeable pavers**

In 2011, the Peel District School Board (PDSB), City of Mississauga and Credit Valley Conservation partnered together to retrofit a portion of a residential collector road, Elm Drive, with LID features to treat road runoff in the ROW and on PDSB school property.

By accepting road runoff on school property the PDSB receives a number of benefits, including:

Improved access to the school – old roadside ditches were replaced with curb and gutter, with new parking lay-bys added for dropping off students. A new sidewalk was also installed.

(Source: Matthew Plexman)

School ground greening – bioretention planters installed at the site not only provide stormwater treatment, but help to green the property, providing a beautifully landscaped amenity for school students, staff and the surrounding community.

The City of Mississauga also benefits from its partnership with the PDSB on this road retrofit through:

Improved water quality – the bioretention planters on PDSB property remove 85-93% of total suspended solids and 92-96% of total phosphorous. This improves the quality of water flowing into nearby Cooksville Creek.

Reduced road runoff – the planters also provide an opportunity for road runoff to infiltrate into the native soils. CVC's monitoring results show that the site can treat up to 90% of events, with only 3-6 events producing runoff to the sewer each year.

For more information, check out the Elm Drive case study in Appendix C

Water quality and stormwater mangement ponds

A growing body of research has shown that conventional end-of-pipe approaches alone do not achieve all of the water quality, erosion, and flood protection benefits they were intended to provide, nor are they fully protecting base flows for assimilative capacity, ecosystems, and biodiversity[56,57,58]. Research in the United States and by the LSRCA, TRCA, and CVC has found stormwater systems relying solely on wet detention ponds are deficient in meeting water quality and erosion criteria[59,60]. As a result, stormwater facilities in some municipalities are creating a compliance liability in addition to providing inadequate water resource protection.

Meet existing and emerging policies

LID can also assist municipalities meet existing and emerging policies that regulate water quality and its impact on ecological function. As an example, the Ontario Endangered Species Act (ESA) provides broader protection for species at risk and their habitats. In response to the ESA, conventional stormwater management techniques are being evaluated against newly developed ESA stormwater management criteria. The Ministry of Natural Resources (MNR) Guidance for Development Activities in Redside Dace Protected Habitat (draft) provides guidance on the best management practices to adopt to avoid or mitigate impacts on the habitat of Redside Dace, a fish species provincially designated as 'At Risk' and protected under the ESA[61].

Case Study: Upper Middle Road Bioretention

LID for Redside Dace

Upper Middle Road is a major east-west arterial road located in the Town of Oakville. As part of a road widening and culvert replacement project on Upper Middle Road in 2011, the Town had a large-scale bioretention facility constructed to provide water quality treatment and water balance benefits for approximately 4 ha of newly constructed roadway.

During the planning phases of the road widening project, Federal, Provincial and local agencies raised concerns over water quality and thermal impacts as well as the maintenance of baseflow to the habitat of Redside Dace, an endangered fish species.

As conventional stormwater management ponds are not able to meet all of the water quality targets necessary for protecting Redside Dace habitat (particularly with respect to mitigating thermal enrichment) bioretention was selected as the preferred alternative. The constructed bioretention facility mitigates thermal pollution, water quality deterioration and an increase in flow volume to the creek. The progressive approach of constructing this facility was endorsed and/or approved through consultation with the Department of Fisheries and Oceans, the Ministry of Natural Resources, and Conservation Halton.

This aerial photograph shows the bioretention facility immediately following construction. Fourteen Mile Creek flows left to right under the roadway. The light brown area is the bioretention cell before plantings have been established. Between the cell and the road is a forebay that provides energy dissipation and pre-treatment. The overflow channel above the forebay only conveys stormwater to the creek during infrequent and intense storm events. (Source: Region of Halton)

As Redside Dace are a cool water species and are sensitive to turbidity, conventional stormwater management techniques are not typically able to provide the necessary treatment to meet these criteria, particularly due to the thermal enrichment that takes place within ponds. A recent road widening project conducted by the Region of Halton in Oakville demonstrates how LID can be used to address these enhanced water quality requirements and thermal impacts. The Upper Middle Road Bioretention ase study has further details.

Combined sewer overflows (CSO)

A combined sewer system is an older standard of sewer system where a single pipe holds both sanitary sewage and stormwater runoff. During periods of dry weather, the design of the sewer uses a dam or similar structure to direct sewage to a treatment facility. During storms, increased flow from stormwater will cause sewage to flow directly into watercourses. This is known to be a major contributor to pollutant loading in urban centers.

By increasing infiltration and evaporation, LID practices reduce the amount of stormwater runoff produced and ease the burden to municipal infrastructure, of particular benefit in the case of CSOs. Because it reduces runoff volumes, LID in the road ROW can effectively reduce the number of overflow events, as well as the associated costs and risks.

The Scarborough waterfront sewershed is serviced by a combination of combined (35%) partially combined (45%) and separated storm-sanitary sewer systems (20%)[62]. Several historical rainfall events have been known to cause flooding within the study area. These events include the May 12, 2000, August 19, 2005, and May 9, 2009 storms. The City of Toronto's Scarborough Waterfront CSO and Stormwater Outfalls Control Class Environmental Assessment (EA) and Flood Protection Study identified storm and combined sewer pollutant loadings to Lake Ontario could be reduced by 10% over a 10 year period and 30% over a 50 year period with the implementation of bioretention in the public right-of-way. The preferred approach, when weighing economic (lifecycle, operation and maintenance and capital costs), environmental, technical and social considerations, is to construct bioretention in the public right-of-way as part of the road resurfacing and/ or road reconstruction program.

The City of Philadelphia found similar savings when conducting a triple-bottom-line (social, economic and environmental) assessment by the City of Philadelphia valued green infrastructure options for CSO control over 40 years. Total present value benefits ranged from $1.9 billion for 25% implementation and more than $4.5 billion for 100% implementation. Portland is investing in low impact development techniques as a mechanism to offset costs related to constructing costly grey infrastructure. The City considers the $9 million invested in LID as a savings of the $224 million in maintenance and repair costs of CSOs[63].

Ontario has as many as 107 combined sewer systems located in 89 municipalities across the province[64]. Moderate CSO abatement strategies where LID controls are part of a broader management plan can result in significant benefits, including financial savings.

Building climate change resilience

As the changing climate increasingly affects weather patterns, it is vital to build resilient communities. In the process, municipalities can expect to face increasing challenges for design, maintenance, operation, and repair of stormwater systems and in-stream protection of water quality, erosion prevention and floodplain management. In the Policy Review of Municipal Stormwater Management in the Light of Climate Change, the MOE's approvals process for municipal stormwater management requires reviews to "include identifying measures to encourage source control best practices for municipal stormwater management[65].

For information on the risks and liabilities facing municipalities, refer to Appendix D.

> Adaptation to climate change based on best available science is a priority for Ontario.
>
> – Ministry of the Environment[66]

Amenity value

From increased green spaces and property values, to improved air quality and ecosystems, LID practices are providing several tangible and intangible benefits beyond simply stormwater management. The broad range of amenities created through LID increases the attractiveness and value (both social and financial) of properties and communities.

A few examples of the environmental, economic and social benefits and include:

- **LID is an important step in re-establishing the balance on which our ecosystems depend.** Recent scientific research evaluating a range of stormwater management treatment options has found conventional pipe and pond treatment configurations alone generally do not meet water quality, water balance, or thermal objectives[67]. So, conventional stormwater management approaches are not only costing municipalities, they are also affecting the health of ecosystems. For instance, the Committee on the Status of Endangered Wildlife in Canada has identified habitat degradation and loss associated with intensive urbanization as the number one threat to the Redside Dace, an endangered fish in Ontario[68]. LID offers improved water quality results and habitat protection for aquatic and terrestrial species.
- **When completed, LID projects incorporate more green space into an area compared to traditional designs.** These additional green spaces in the form of plantings, bioretention areas, swales, and filter strips are commonly perceived as enhancing the aesthetics of the community or city. Planting can also increase the sense of privacy on a lot or neighbourhood level by creating simple transitions from public to private spaces. In addition, vegetated landscapes generally promote a healthier work environment. Encounters with everyday nature, including a view from an office window, a walk through a garden or well-tended landscape helps to restores the ability to concentrate, calm feelings of anxiety and reduces aggression. Research demonstrates that response to trees and vegetation can be linked to health, and in turn related to economic benefits[69]. In fact, a view of natural setting reduces the number of sick days taken by office workers[70].
- **People are generally willing to pay more for real estate with green features.** A study from Anderson and Cordell demonstrated that buyers in California paid an increase of 3.5% to 4.5% per home when the properties features included landscaping and trees[71]. More recent studies conducted in Philadelphia, Portland, and Washington State concluded that green infrastructure and street tree plantings increase the value of local property by as much as 10%[72], whereas Mohamed[73] found property value increases ranging from 12 to 16% while averaging $7,400 (USD) less per lot to produce in Rhode Island.
- **Commercial districts enhanced with LID features tend to show similar benefits with higher occupancy rates and enhanced property values.** Commercial properties where landscape amenities have the highest correlation with occupancy rates from a list of 30 variable including building architecture, urban design and direct access to arterial routes[74]. A surveys of real-estate appraisers found that 86% acknowledged that landscaping added to the dollar value commercial properties, with 92% agreeing that landscaping enhances the sales appeal of commercial real estate.

Figure 1.3.2: Bioretention planters are an integral part of Kitchener's new King Street streetscape. They not only help manage stormwater runoff from the road, but they also provide amenity value through street greening and providing pedestrians with a gathering space. (Source: City of Kitchener)

- **LID supports green job development.** As LID practices increase, the demand for related products, materials, and skills will also increase. This demand will create green jobs among materials suppliers, product manufacturers and will drive growth in workers skilled in LID implementation. These workers include designers (engineers and architects), installers (site service contractors and landscaping firms), long-term operation and maintenance staff (grounds maintenance personnel and dedicated LID management crews), and others employed in related professions.

1.4 Financing LID retrofits and overcoming barriers to LID

Financing LID retrofits

Finding the necessary funding to finance investments in stormwater management infrastructure can be challenging. Many Ontario municipalities are facing infrastructure deficits, where investments in upgrading aging stormwater infrastructure must compete with meeting the demands of new development. There are a number of tools, however, that municipalities can use to finance road ROW retrofits. These include:

- Federal Gas Tax Fund
- Ministry of Infrastructure funding
- Stormwater rate

Federal Gas Tax Fund

Did you know that you can use the federal Gas Tax Fund (GTF) to fund stormwater projects? The GTF is a long-term, flexible and predictable source of funding for municipalities to invest in infrastructure and long-term planning projects that improve Asset Management. These investments can be made in 17 categories of infrastructure, including stormwater.

In Ontario, the GTF is administered by Association of Municipalities of Ontario (AMO) and distributed to municipalities on a per-capita basis. The GTF is very flexible - local municipal councils have the ability to invest in their priority projects. It can be used as the sole source, or part of multiple funding sources – to fund up to 100% of an infrastructure project. The fund can also be used to pay down debt incurred by investments in sustainable infrastructure projects or can banked up to five years for future use.

Several municipalities in Ontario are using the GTF to invest in stormwater management. In 2012 alone, 18 stormwater-related projects were completed, benefiting from Gas Tax Funds[75].

Figure 1.4.1: The Federal Gas Tax Fund is not just for building roads. Municipalities can apply for funding for a variety of infrastructure projects, including stormwater management.

City of Brampton invested approximately $80,000 in the design and construction of two 75 m long bioswales on County Court Boulevard as part of the Sustainable Neighbourhood Retrofit Action Plan (SNAP) to improve the quality of runoff entering Etobicoke Creek [76].

City of Barrie has invested $100,000 of their GTF to develop a stormwater management asset management plan . This award winning plan will help the city to make informed decisions regarding infrastructure maintenance, repair and replacement requirements[77].

Richmond Hill invested $65,000 of their GTF allocation to study and implement a new sustainable funding model for stormwater management infrastructure[78].

Town of Halton Hills invested $13,000 of its GTF allocation into improving several stormwater quality control structures. This project will improve the quality of water in the Credit River watershed[79].

For more information on the federal Gas Tax Fund in Ontario, visit gastaxatwork.ca

Ministry of Infrastructure funding

The Ontario Ministry of Infrastructure has a municipal infrastructure strategy that requires long-term asset management planning by municipalities seeking provincial capital funding. Given the pressures facing municipalities today, including growing infrastructure deficits and increasing development pressures, the strategy will support infrastructure needs for today and into the future.

There are many principles that guide the strategy including the need for "comprehensive asset management plans to guide investment decisions" and Ontario municipalities are required to develop asset management plans to support request for infrastructure funding.

The MOI's Building Together: Guide for Municipal Asset Management Plans, outlines the required content for asset management plan submissions to the Province. Larger municipalities may already have asset management plans in place whereas smaller municipalities have financial limitations to undertake asset management planning. This guide will support small, medium and large municipalities by providing information about green infrastructure that will support the preparation of asset management plans.

For information on how LID can help you meet Provinicial Asset Management requirements, refer to Appendix B.

Stormwater rate

Another source of funding for municipalities to finance stormwater management infrastructure that is gaining popularity in Ontario is a stormwater rate. This fee system charges property owners a fee based upon the amount of stormwater runoff they generate. These programs can provide a dedicated source of funds to implement stormwater infrastructure projects, including LID retrofits within the road ROW.

The City of Waterloo and City of Kitchener have led the implementation of this program in Ontario, introducing the program in 2010. Other municipalities have implemented, or are in the process of implementing, similar programs. Adopting this type of program in your municipality may give you greater opportunities to implement LID retrofits within the ROW.

Overcoming barriers to LID

Despite provincial support for LID through the MOE's Stormwater Management Planning and Design Manual and the Stormwater Policy Review in Light of Climate Change as well as municipal support (Great Lakes Cities Initiative, Toronto's Wet Weather Flow Management Guidelines and Mississauga's Water Quality Strategy) the adoption of LID for new development or retrofit of existing urban areas has not been widespread across Ontario. This is because many barriers and misconceptions still exist when it comes to implementing LID.

For more information on addressing barriers to road retrofits, refer to the case studies in Appendix C and list of common barriers to LID adoption has been compiled in Appendix E.

2.0 LID Options For Road ROWs

This chapter provides an overview of the LID options that are best suited for road ROWs. Given the wide variety of options, selecting the ones that will best meet your needs may seem daunting. To help you identify the best option(s) for your road retrofit project, the following information is provided for each LID option:

- A brief description
- Photograph(s) of the practice implemented within a ROW setting
- A Suitability & Considerations table that provides supplementary information
- An illustrated rendering of the LID practice showing key features

With this information you should have a better idea of the LID options that meet your needs. Further guidance on screening LID practices is provided in Chapter 4.

For further information on the LID options, see the LID Design Guide at

bealeader.ca

Bioretention

- Bioretention planters
- Bioretention curb extensions
- Boulevard bioretention units

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Swales

- Enhanced grass swales
- Bioswales

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Perforated Pipes

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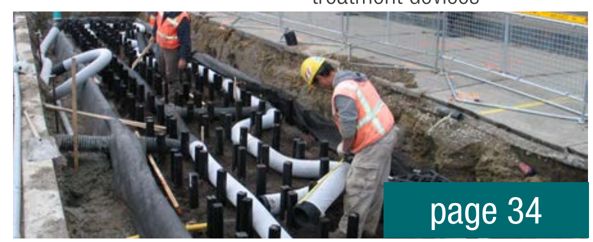
Prefabricated Modules

- Precast tree planters
- Soil support systems
- Phosphorus removal
- Proprietary stormwater treatment devices



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Permeable Pavement

- Pervious concrete
- Porous asphalt
- Permeable pavers

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2.1 Bioretention

Bioretention are vegetated practices that temporarily store, treat and infiltrate stormwater runoff. The most important component of these practices is the bioretention soil media. The bioretention soil media is made up of a specific ratio of sand, fine soils and organic material.

Bioretention can be integrated into a diverse range of landscapes and land uses. For road ROWs, bioretention units are most commonly located along boulevards, but they can also be constructed in medians, cul-de-sac islands and in curb extensions. Try customizing planting and landscaping treatments within a bioretention area to provide aesthetic value and contribute positively to the character of the surrounding properties.

Bioretention areas are key components of stormwater management strategies meant to preserve local pre-development water balance as they reduce runoff volume through the processes of infiltration and evapotranspiration. Bioretention also improves stormwater quality through a variety of physical, biological, and chemical treatment processes.

Depending on the native soil infiltration rate and site constraints, bioretention practices may be designed without an underdrain for full infiltration, with an underdrain for partial infiltration, or with an impermeable liner and underdrain for filtration only (i.e., a biofilter).

Vegetation maintenance requirements of bioretention are similar to those of other landscaped areas and include trash removal, weeding, replacing dead vegetation, and checking for clogging of inlets and outlets. The effort will vary based upon the type of vegetation; bioretention with only grass requires the least amount of effort, while formal garden designs need more maintenance.

Selecting either grass or plants for a particular bioretention practice depends on a variety of factors. In general, planted bioretention areas are recommended for higher profile settings where sufficient municipal resources (financial and staff time) can be dedicated to building community buy-in and conducting regular inspection and maintenance.

Some of the pros and cons of grass- and plant-based bioretention areas are listed in Table 2.1.1.

Perception: Plants are the only source of vegetation in bioretention

Reality: In fact, the term bioretention refers to the bioretention soil media that forms the base for the practice. The landscaped area can include turf or plants.

Table 2.1.1: Comparing grass to plant swales

Grass	
Pros	• Lower O&M requirements • Looks like typical street turf landscaping
Cons	• Lower aesthetic value • Lacks visual cues that infiltration features are present • Reduced performance compared to planted bioretention areas[77]
Plants	
Pros	• Greater visual appeal • Greater profile in the community • Achieve multiple objectives (stormwater management, community greening)
Cons	• Greater effort by staff to gain buy-in from residents • Greater O&M requirements

Bioretention planters

Bioretention planters have vertical sidewalls and are often narrow and rectangular in shape. The walls allow bioretention planters to maximize the amount of stormwater retention within a small footprint.

The self-contained structure of bioretention planters permits them to be installed in close proximity to utilities, driveways, trees, light standards and other landscape features. Bioretention planters can be constructed immediately adjacent to the roadway, in the boulevard, or as a green feature within the pedestrian area (i.e. sidewalks and pathways). Given these characteristics, bioretention planters are ideal for integrating within highly urbanized streetscapes or within other road ROWs with tight space constraints.

Planters are an ideal means to address multiple objectives in urban streetscapes, including street greening and improved aesthetics along with stormwater management benefits.

For examples of bioretention planters installed and operating in an Ontario municipality, refer to the Elm Drive case study in Appendix C.

Suitability	
High	High density
Moderate	Medium density
Low	Low density

Low Suitability / Moderate / High

Municipal Staff & Financial Considerations	
High	Community engagement
High	Inter-departmental co-ordination
High	Design team
High	Capital cost
High	Operation & maintenance costs

Low Effort/Cost / Moderate / High

Design Considerations	
Moderate	Geotechnical testing complexity
Moderate	Infiltration testing complexity
High	Planning complexity
Moderate	Design complexity

Low Effort / Moderate / High

Benefits	
Moderate	Flood risk reduction (water quantity)*
High	Pollutant removal (water quality)
High	Groundwater recharge (water balance)*
High	Stream channel erosion control
High	Amenity & aesthetic value
Low	Traffic calming
High	Urban tree canopy
High	High profile with community & media

Low Benefits / Moderate / High

*Performance will vary based upon site characteristics and design of LID practice.

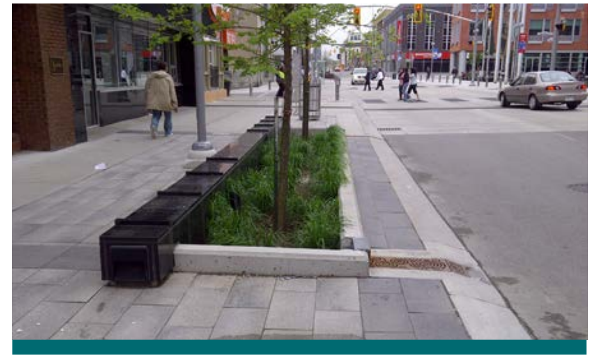


Figure 2.1.1: Bioretention planters can incorporate multiple features. The bioretention planters on King Street in Kitchener provide growing media for street trees, seating for pedestrians, and street lighting (accent lighting within the planters). (Source: Aquafor Beech)

Figure 2.1.2: Bioretention planters aren't just for highly urbanized road ROWs. Planters were used to retain additional road runoff from Elm Drive in Mississauga. (Source: CVC)

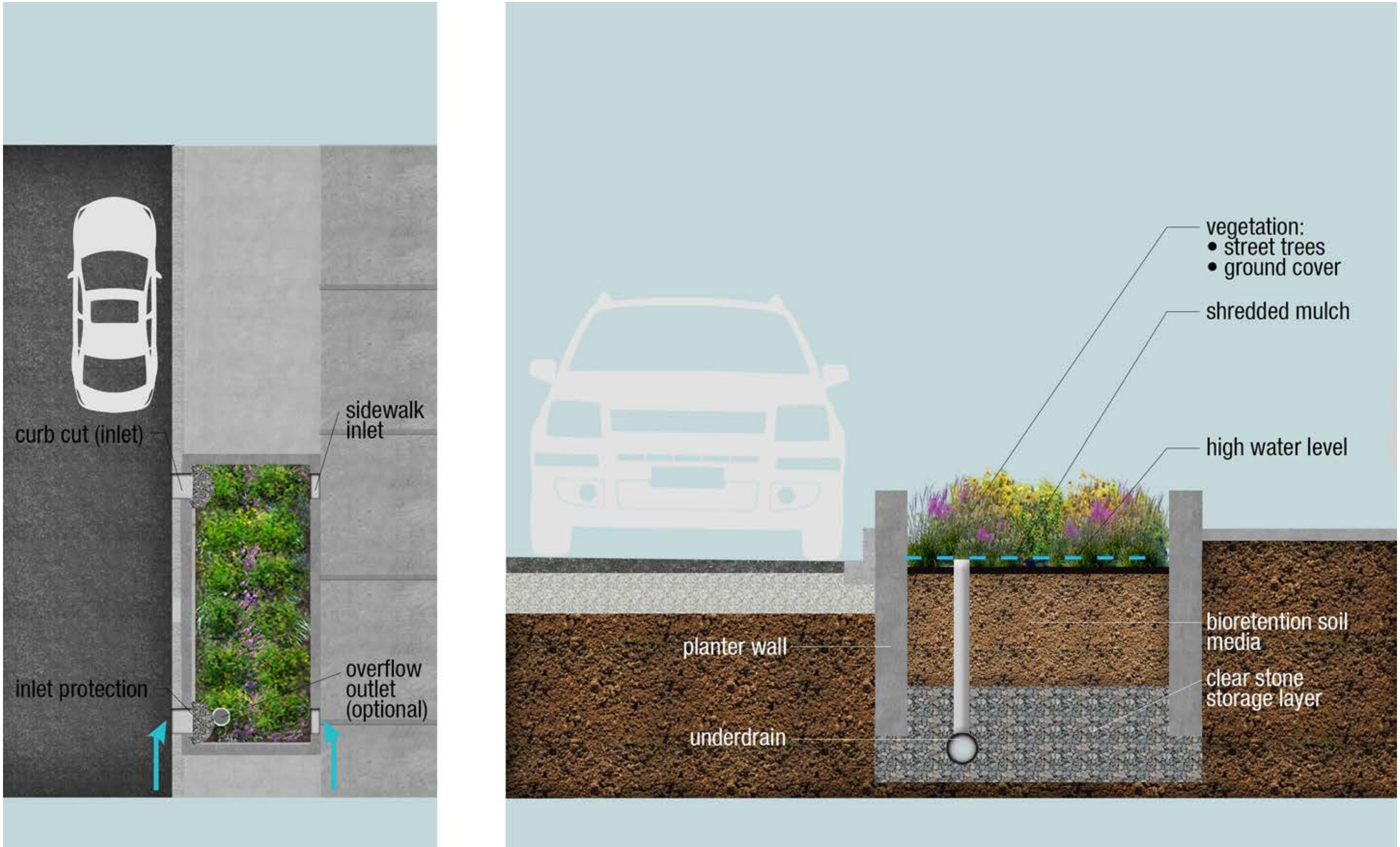


Figure 2.1.3: Bioretention planter plan view [left] and cross-section [right]

Bioretention curb extensions

Bioretention curb extensions, also known as curb bump-outs, are bioretention areas that extend into the roadway and are separated by perimeter curbing. Construction of bioretention curb extensions requires fewer disturbances to the ROW than other LID retrofit options.

Bioretention curb extensions can be used for traffic calming. They can create a safer pedestrian zone by increasing the buffer width between the sidewalk and roadway.

Curb extensions are a very flexible LID retrofit option. It's easy to accommodate their construction during road resurfacing, road construction, or road reduction projects. The location, size and spacing of bioretention curb extensions can be adjusted as needed to meet existing roadway conditions. It's possible to design them so the existing curb and stormwater inlets remain in place.

One disadvantage is that curb extensions can reduce the amount of on-street parking and can impact the traffic capacity of a road. In some cases, municipalities may require traffic and parking studies to evaluate the potential impacts.

	Suitability
◉	High density
●	Medium density
●	Low density

○ Low Suitability ◉ Moderate ● High

	Municipal Staff & Financial Considerations
●	Community engagement
●	Inter-departmental co-ordination
◉	Design team
◉	Capital cost
◉	Operation & maintenance costs

○ Low Effort/Cost ◉ Moderate ● High

	Design Considerations
○	Geotechnical testing complexity
◉	Infiltration testing complexity
◉	Planning complexity
◉	Design complexity

○ Low Effort ◉ Moderate ● High

	Benefits
◉	Flood risk reduction (water quantity)*
●	Pollutant removal (water quality)
●	Groundwater recharge (water balance)*
●	Stream channel erosion control
●	Amenity & aesthetic value
●	Traffic calming
○	Urban tree canopy
●	High profile with community & media

○ Low Benefits ◉ Moderate ● High

*Performance will vary based upon site characteristics and design of LID practice.

Figure 2.1.4: Bioretention curb extensions can be part of a street reduction, where a lane within the roadway can be dedicated to other uses such as street parking, bicycle lanes, pedestrian crossings, and street greening. (Source: CVC)

Figure 2.1.5: Curb extensions can be built to accommodate existing locations of stormwater management infrastructure, such as catch basins. (Source: CVC)

Figure 2.1.6: Bioretention curb extension plan view [left] and cross-section [right]

Boulevard bioretention units

Boulevard bioretention units are most commonly used along low density residential ROWs. They are shallow vegetated depressions located immediately behind the curb. For streetscapes with sidewalks, these units are located between the curb and inside sidewalk edge. In residential areas that do not have sidewalks, these cells are located on the municipally-owned portion of the boulevard.

A primary advantage of boulevard bioretention units is versatility in size and shape. Unlike bioretention planters, these practices do not require the on-site container construction, which reduces construction costs. Curb cuts typically direct road drainage to a bioretention cell, though other inlet types, such as side inlets, can be designed to meet site needs.

Boulevard bioretention units can be integrated into road resurfacing, road construction, and road reduction projects. These units are ideal for road reconstruction of residential rural cross sections, as they provide a cost savings.

For more information on road ROW retrofits with boulevard bioretention, refer to the Lakeview Project case study in Appendix C.

Suitability	
○	High density
◎	Medium density
●	Low density

○ Low Suitability ◎ Moderate ● High

Municipal Staff & Financial Considerations	
●	Community engagement
●	Inter-departmental co-ordination
●	Design team
◎	Capital cost
◎	Operation & maintenance costs

○ Low Effort/Cost ◎ Moderate ● High

Design Considerations	
●	Geotechnical testing complexity
●	Infiltration testing complexity
◎	Planning complexity
◎	Design complexity

○ Low Effort ◎ Moderate ● High

Benefits	
◎	Flood risk reduction (water quantity)*
●	Pollutant removal (water quality)
●	Groundwater recharge (water balance)*
●	Stream channel erosion control
◎	Amenity & aesthetic value
○	Traffic calming
○	Urban tree canopy
●	High profile with community & media

○ Low Benefits ◎ Moderate ● High

*Performance will vary based upon site characteristics and design of LID practice.

Figure 2.1.7: Boulevard bioretention units are ideally suited for road reconstruction projects upgrading residential streets with a rural cross section to an urban cross-section. This photo shows a home in the Lakeview neighbourhood in Mississauga with a planted boulevard bioretention unit. (Source: CVC)

Figure 2.1.8: Residents were given the opportunity to select either planted or grass bioretention units. This photograph shows one of the grass bioretention units in front of a property. (Source: CVC)

Figure 2.1.9: Boulevard bioretention unit plan view [left] and cross-section [right]

2.2 Swales

Simple grass channels, generally referred to as ditches are commonly used for stormwater conveyance, particularly for roadway drainage in rural settings. Swales incorporate a number of simple modifications to the standard ditch design to substantially improve pollutant removal and runoff reduction capability. Swale design features can include modified geometry (a wider channel base coupled reduced side slopes), check dams, vegetation, and/or bioretention soil media.

Unlike bioretention units, swales are designed for the primary purpose of conveying strormwater from one location to another. Stormwater retention and treatment are secondary objectives of these designs.

Enhanced grass swales

Enhanced grass swales are vegetated open channels designed to convey, treat, and attenuate stormwater runoff. Check dams and vegetation in the swale slows the water to allow sedimentation, filtration through the root zone and soil, evapotranspiration, and infiltration into the underlying native soil.

As a stormwater conveyance system, an enhanced grass swale is a preferred alternative to curb-and-gutter installations and storm drains. When incorporated into a site design, swales can reduce impervious cover, accent the natural landscape, and provide aesthetic benefits.Since they lack the engineered soil media and storage capacity, enhanced grass swales are not capable of providing the same water balance and water quality benefits as bioswales.

Figure 2.2.1: Enhanced grass swales have been implemented successfully throughout the United States and Canada. (Source: CVC)

Suitability	
○	High density
◎	Medium density
●	Low density

○ Low Suitability ◎ Moderate ● High

Municipal Staff & Financial Considerations	
○	Community engagement
○	Inter-departmental co-ordination
○	Design team
○	Capital cost
○	Operation & maintenance costs

○ Low Effort/Cost ◎ Moderate ● High

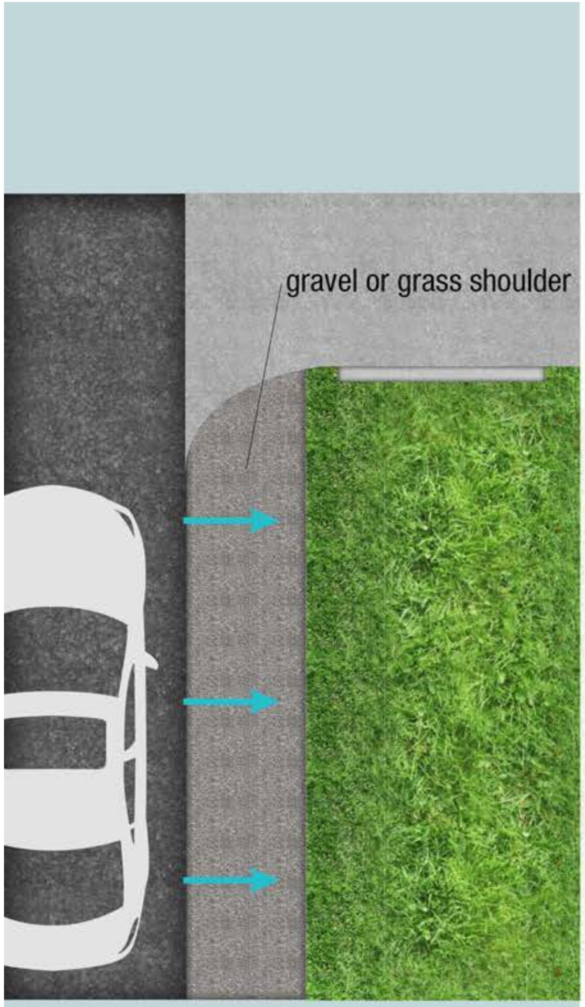
Design Considerations	
◎	Geotechnical testing complexity
◎	Infiltration testing complexity
○	Planning complexity
○	Design complexity

○ Low Effort ◎ Moderate ● High

Benefits	
○	Flood risk reduction (water quantity)*
◎	Pollutant removal (water quality)
◎	Groundwater recharge (water balance)*
◎	Stream channel erosion control
◎	Amenity & aesthetic value
○	Traffic calming
○	Urban tree canopy
○	High profile with community & media

○ Low Benefits ◎ Moderate ● High

*Performance will vary based upon site characteristics and design of LID practice.



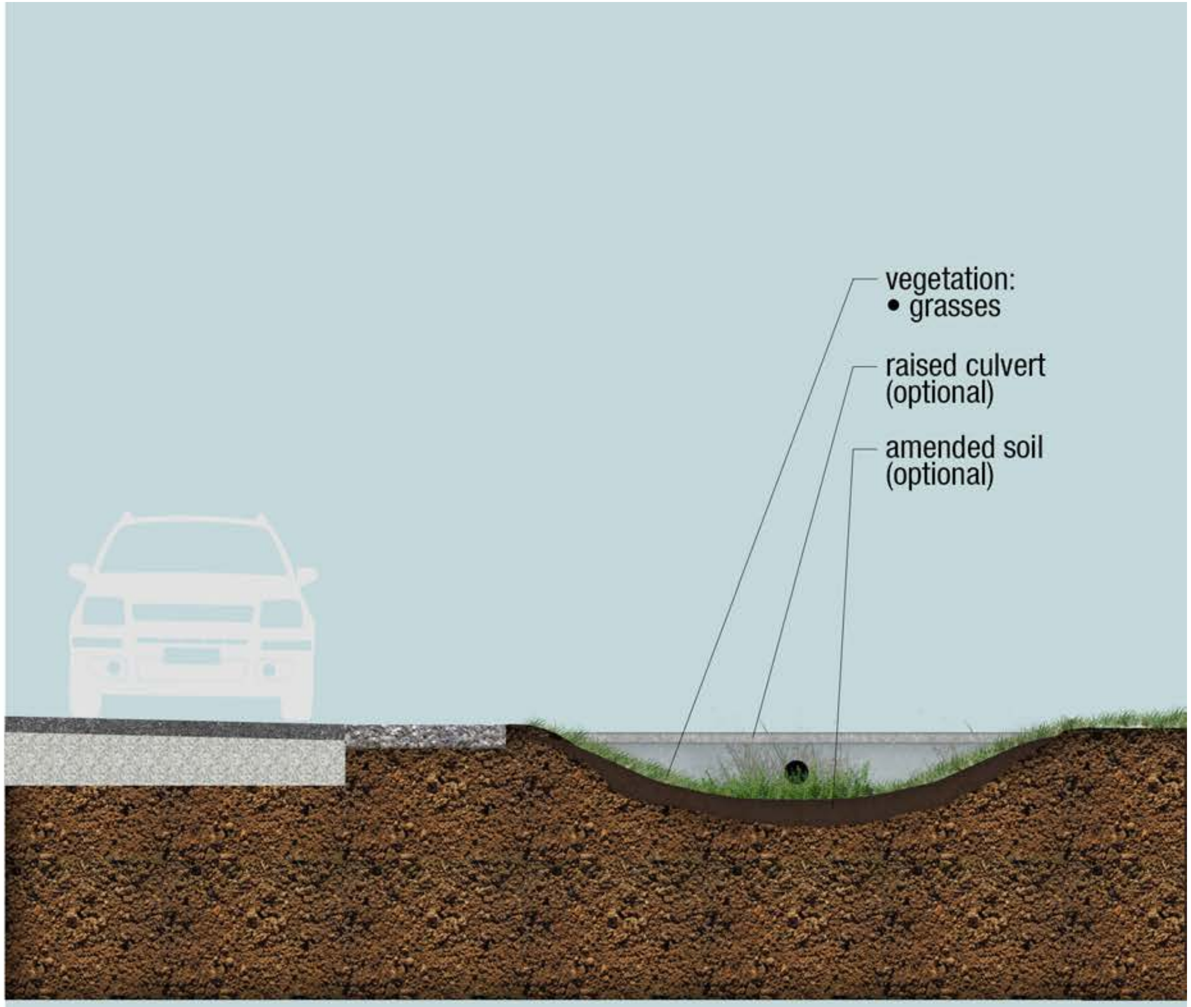


Figure 2.2.2: Enhanced grass swale plan view [left] and cross-section [right]

Bioswales

Bioswales are similar to enhanced grass swales in terms of the design of their surface geometry, slope, and optional use of check dams. Bioswales also incorporate aspects of bioretention cells—they have bioretention soil media, a gravel storage layer, and optional underdrain components.

When compared to curb-and-gutter or ditch conveyance systems, bioswales can significantly enhance neighbourhood aesthetics. They are appropriate for low-to-medium density residential development. They are not viable options for high-density development due to their requirement for significant continuous lengths of impervious surface.

Figure 2.2.3: It is important that the planting plan fits within the character of the community. (Source: CVC)

Bioswales are vegetated open channels that incorporate engineered bioretention soil media and an optional perforated pipe underdrain. Just like bioretention units, there are two variations of bioswales based on the type of vegetation: grass and planted.

Enhanced grass swales are vegetated open channels designed to convey, treat and attenuate stormwater runoff. They do not have bioretention media or underdrains.

What's in a name?

The term bioswale is often mistakenly applied to any type of vegetated conveyance practice, but there are different types of swales, each providing their own level of stormwater treatment.

Figure 2.2.4: Combining LID retrofits with educational signage is an excellent way to raise awareness of water issues among residents. (Source: CVC)

Suitability	
○	High density
◎	Medium density
●	Low density

○ Low Suitability ◎ Moderate ● High

Municipal Staff & Financial Considerations	
●	Community engagement
●	Inter-departmental co-ordination
●	Design team
◎	Capital cost
◎	Operation & maintenance costs

○ Low Effort/Cost ◎ Moderate ● High

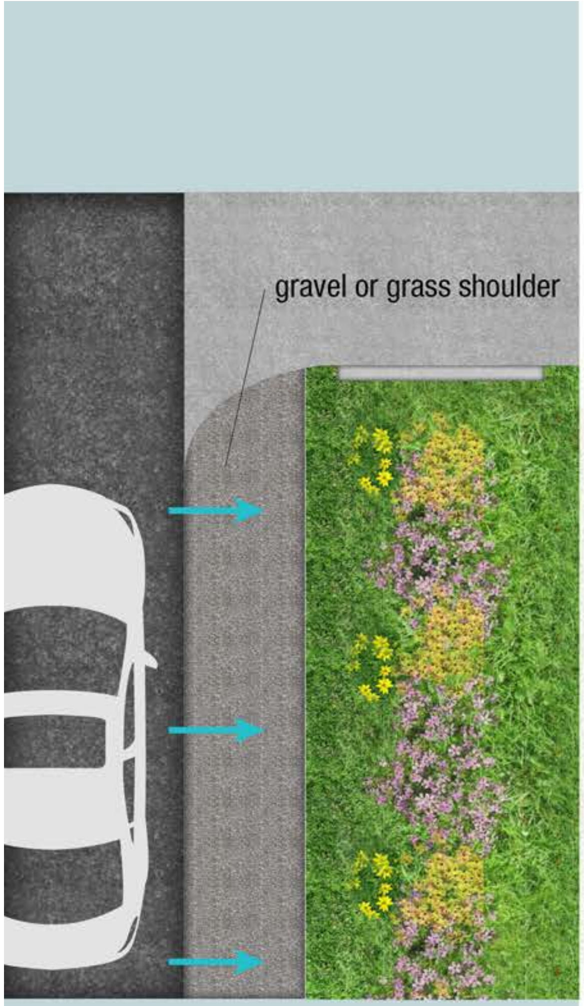
Design Considerations	
●	Geotechnical testing complexity
●	Infiltration testing complexity
◎	Planning complexity
◎	Design complexity

○ Low Effort ◎ Moderate ● High

Benefits	
◎	Flood risk reduction (water quantity)*
●	Pollutant removal (water quality)
●	Groundwater recharge (water balance)*
●	Stream channel erosion control
◎	Amenity & aesthetic value
○	Traffic calming
○	Urban tree canopy
●	High profile with community & media

○ Low Benefits ◎ Moderate ● High

*Performance will vary based upon site characteristics and design of LID practice.



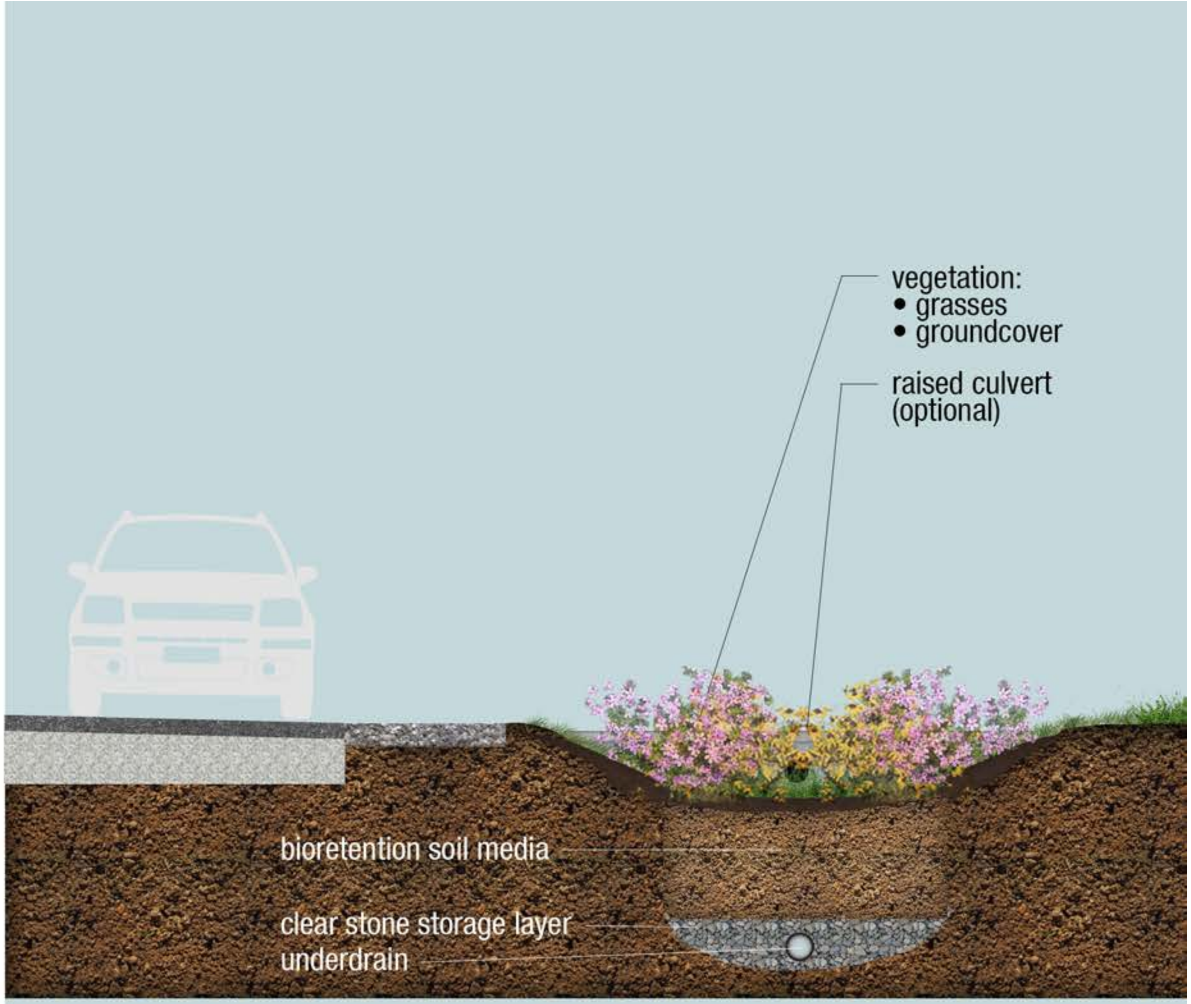


Figure 2.2.5: Bioswale plan view [left] and cross-section [right]

2.3 Perorated Pipe

Perforated pipe systems, also called exfiltration systems, can be thought of as long infiltration trenches that are designed for both conveyance and infiltration of stormwater runoff. They are underground stormwater conveyance systems composed of perforated pipes installed in gently sloping granular stone beds lined with geotextile fabric that allows infiltration of runoff into the gravel bed and underlying native soil.

Perforated pipe systems can be used in place of conventional storm sewer pipes where topography, water table depth, and runoff quality conditions are suitable. They are capable of handling runoff from roofs, walkways, parking lots, and low-to-medium traffic roads. For areas of high pollutant loading, use pre-treatment.

Typically, perforated pipe can be implemented with less dedicated staff time and resources than bioretention practices. Because these practices are buried and the streetscape remains largely the same as conventional curb-and-gutter, it requires less effort to secure buy-in from residents to construct practices in the boulevard or in the roadway.

Suitability	
●	High density
●	Medium density
●	Low density

○ Low Suitability ◉ Moderate ● High

Municipal Staff & Financial Considerations	
○	Community engagement
○	Inter-departmental co-ordination
○	Design team
○	Capital cost
○	Operation & maintenance costs

○ Low Effort/Cost ◉ Moderate ● High

Design Considerations	
◉	Geotechnical testing complexity
◉	Infiltration testing complexity
○	Planning complexity
○	Design complexity

○ Low Effort ◉ Moderate ● High

Benefits	
◉	Flood risk reduction (water quantity)*
◉	Pollutant removal (water quality)
●	Groundwater recharge (water balance)*
●	Stream channel erosion control
○	Amenity & aesthetic value
○	Traffic calming
○	Urban tree canopy
○	High profile with community & media

○ Low Benefits ◉ Moderate ● High

*Performance will vary based upon site characteristics and design of LID practice.

Figure 2.3.1: Perforated pipe systems employ many of the same materials and construction practices as conventional storm sewer pipes, instead using perforated pipes to encourage infiltration during conveyance. (Source: Aquafor Beech)

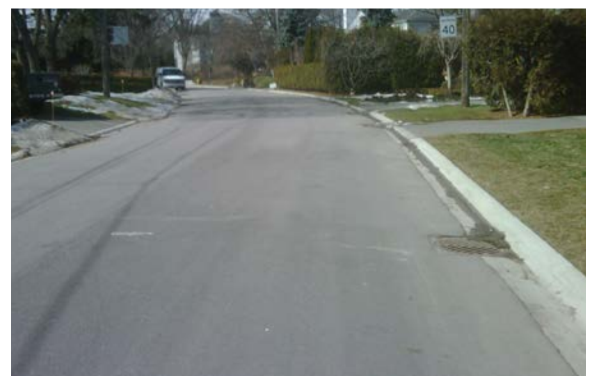


Figure 2.3.2: Streets with perforated pipe don't look any different from conventional curb-and-gutter streets, an advantage in neighbourhoods where residents do not want to change the character of the street. (Source: Aquafor Beech)

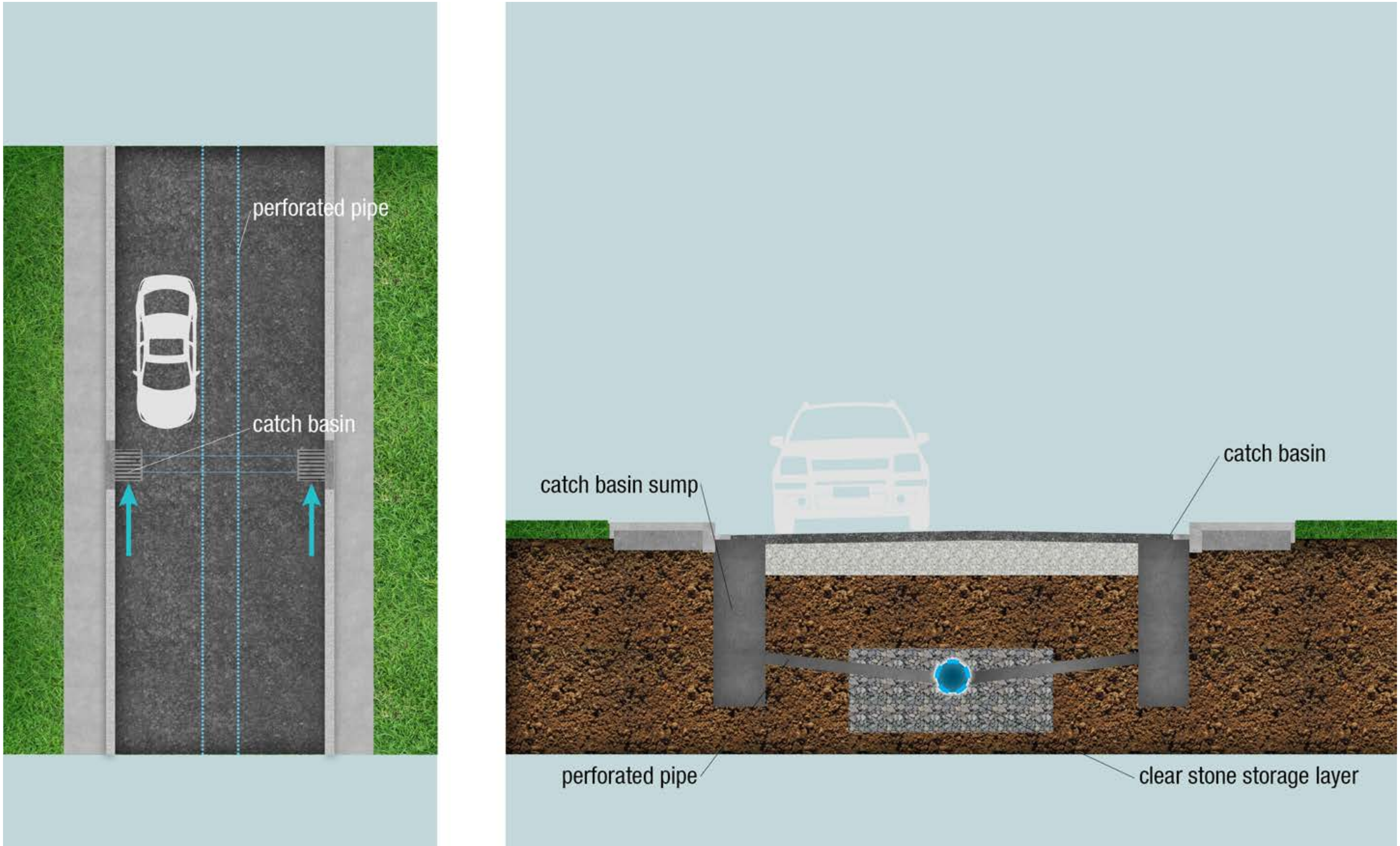


Figure 2.3.3: Perforated pipe plan view [left] and cross-section [right]

Prefabricated modules

2.4 Prefabricated modules

Prefabricated modules provide municipalities with additional options for implementing LID retrofits. The main benefit of this option is that product specifications are readily available from manufacturers, along with design guidance, installation considerations, and expected performance. This support can help provide confidence to municipalities not experienced with LID retrofits, as well as municipalities seeking a more off-the-shelf retrofit process.

Many prefabricated modules are designed primarily for stormwater treatment, so the use of these products may not address quantity and water balance. These types of prefabricated modules are ideal as pre-treatment for other LID practices like perforated pipe. If quality control isn't required, prefabricated modules can be used on their own, or for units that manage both stormwater quantity and quality.

Precast tree planters

Precast tree planters are prefabricated enclosures that contain trees or shrubs, bioretention soil media, and a perforated pipe underdrain outlet. These systems are designed to collect stormwater runoff from roads and sidewalks and treat it using bioretention. Tree planters can be dropped in place, but, unlike bioretention planters, they cannot be custom-sized and designed for a particular site.

Due to the concrete bottom, these planters do not provide water balance benefits; however, when combined as pre-treatment for a downstream perforated pipe system, these planters can provide comprehensive watershed water balance protection.

Figure 2.4.1: A Filterra Bioretention System (the flowering plantings and buried precast unit pictured above) is one type of precast tree planter.(Source: Filterra Bioretention Systems)

Due to the rapid evolution of prefabricated modules, contacting the suppliers directory for up-to-date product information is strongly recommended.

	Suitability
●	High density
●	Medium density
●	Low density

○ Low Suitability ◎ Moderate ● High

	Municipal Staff & Financial Considerations
◎	Community engagement
●	Inter-departmental co-ordination
◎	Design team
●	Capital cost
◎	Operation & maintenance costs

○ Low Effort/Cost ◎ Moderate ● High

	Design Considerations
○	Geotechnical testing complexity
○	Infiltration testing complexity
◎	Planning complexity
○	Design complexity

○ Low Effort ◎ Moderate ● High

	Benefits
○	Flood risk reduction (water quantity)*
◎	Pollutant removal (water quality)
○	Groundwater recharge (water balance)*
◎	Stream channel erosion control
●	Amenity & aesthetic value
○	Traffic calming
●	Urban tree canopy
◎	High profile with community & media

○ Low Benefits ◎ Moderate ● High

*Performance will vary based upon site characteristics and design of LID practice.

Figure 2.4.2: Pre-cast tree planter plan view [left] and cross-scetion [right]

Soil support systems

When soils are heavily compacted (especially in heavily urbanized areas) water does not percolate as effectively. As a result, urban tree growth can be severely stunted, reducing the infiltration capacity of the native soil. Conversely, soil that is not sufficiently compacted can result in settling and failure of infrastructure located above it.

Soil support systems address both of these issues. These systems consist of modular frames (or cells) that provide structural support for paved surfaces without the need for a compacted soil base within the tree root zone.

Each cell can hold a specified volume of soil. Cells can be spread across a wide surface area and stacked on top of each other to a specified depth, creating very large tree root zones and infiltration areas beneath infrastructure, particularly sidewalks. These systems are particularly beneficial for municipalities aiming to improve the health and canopy of urban trees.

Suitability	
●	High density
◎	Medium density
○	Low density

○ Low Suitability ◎ Moderate ● High

Municipal Staff & Financial Considerations	
○	Community engagement
◎	Inter-departmental co-ordination
◎	Design team
●	Capital cost
◎	Operation & maintenance costs

○ Low Effort/Cost ◎ Moderate ● High

Design Considerations	
●	Geotechnical testing complexity
◎	Infiltration testing complexity
◎	Planning complexity
●	Design complexity

○ Low Effort ◎ Moderate ● High

Benefits	
◎	Flood risk reduction (water quantity)*
●	Pollutant removal (water quality)
●	Groundwater recharge (water balance)*
●	Stream channel erosion control
●	Amenity & aesthetic value
○	Traffic calming
●	Urban tree canopy
◎	High profile with community & media

○ Low Benefits ◎ Moderate ● High

*Performance will vary based upon site characteristics and design of LID practice.

Figure 2.4.3: Installing the soil support system under the sidewalk on part of the Queensway in Toronto. (Source: Deep Root Inc.)

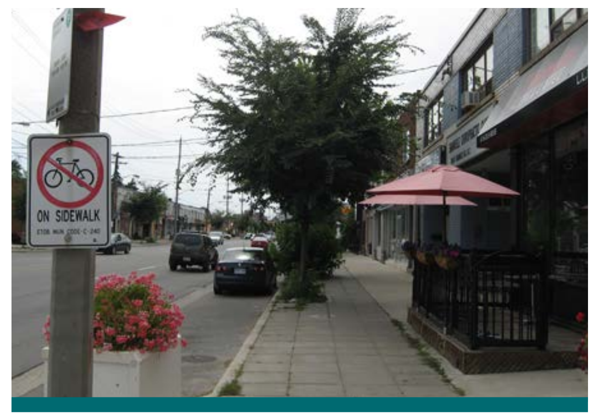


Figure 2.4.4: Sidewalk following construction, showing healthy trees. (Source: Deep Root Inc.)

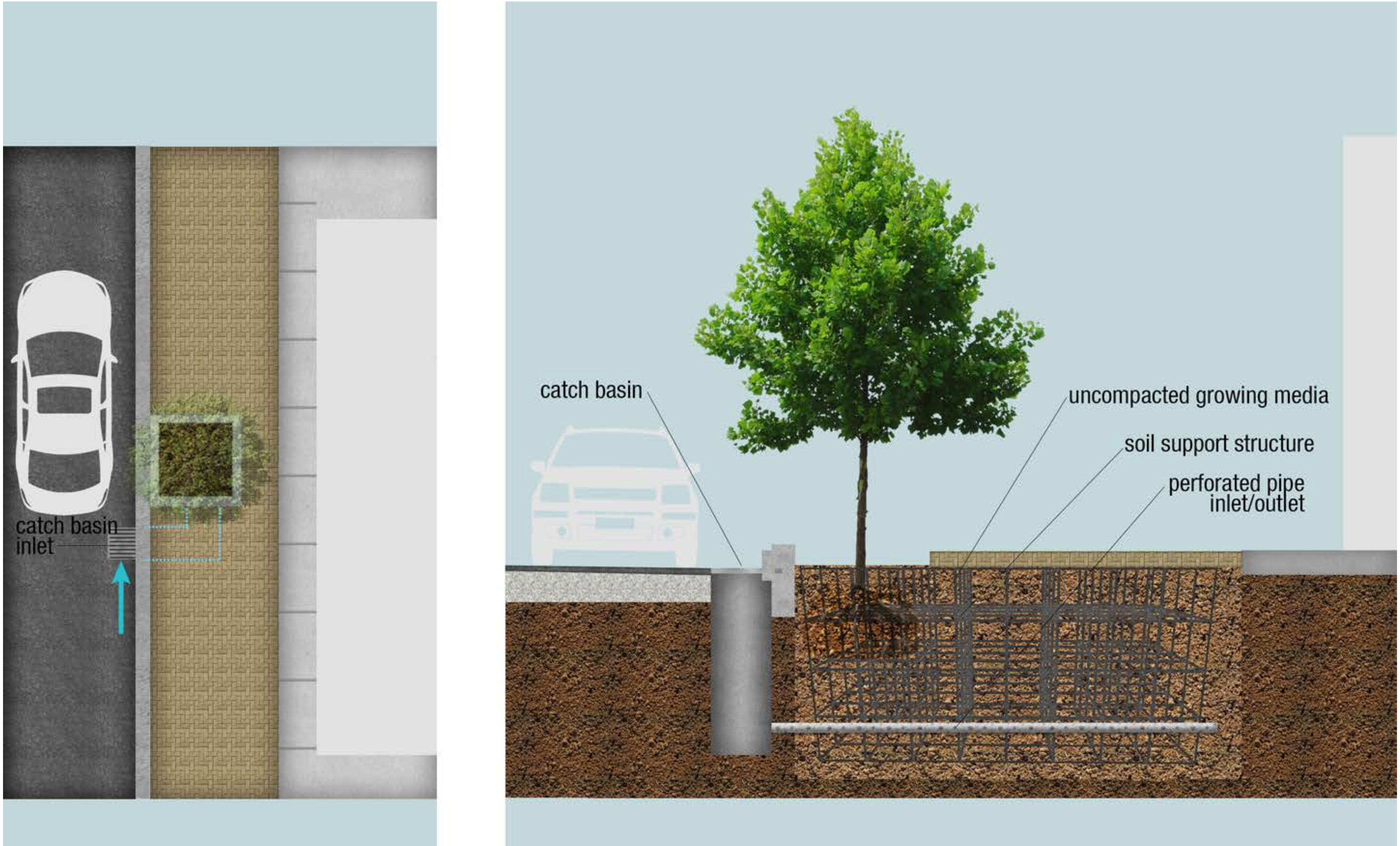


Figure 2.4.5: Soil support system plan view [left] and cross-section [right]

Phosphorus removal media

Phosphorus is a pollutant of concern in many Ontario watersheds. Excess phosphorus loading can result in the growth of nuisance algae, loss of prey fish, degradation of drinking water, and beach closures. For catchments where loading is a significant concern, phosphorus removal media can help municipalities address this issue.

One type of phosphorus removal media is an oxide-coated, high surface area reactive engineered media. Another means for reducing phosphorus loading is the use of natural products or industrial by-products such as red sand filter media. Red sand has been found to have a phosphorus retention capability, and its performance is currently being evaluated by the Lake Simcoe Region Conservation Authority. Refer to the George Richardson case study in Appendix C to learn more.

Proprietary stormwater treatment devices

Proprietary stormwater treatment devices cover a broad range of different technologies and processes. In general, they are comprised of a prefabricated enclosure into which proprietary technologies are added to treat stormwater runoff. Some of the treatment approaches include: hydrodynamic systems (commonly called oil and grit separator devices), wet vaults, and media filters.

The suspended solids, metals, and oils/floatables removal characteristics of proprietary stormwater treatment devices can vary widely. Like all stormwater management practices their performance depends upon regular inspection and maintenance. To maximize the treatment and water balance benefits, it is recommended that these devices be used as part of a treatment train and located upstream of an LID practice. For an example refer to the IMAX Project case study in Appendix C.

Figure 2.4.6: Engineered media such as phosphrous removal media use a variety of mechanisms to absorb and retain dissolved phosphorus. (Source: Aquafor Beech)

Figure 2.4.7: To maximize treatment and water balance benefits, proprietary stormwater treatment devices can be installed upstream of LID practices. (Source: CVC)

Suitability	
●	High density
●	Medium density
◉	Low density

○ Low Suitability ◉ Moderate ● High

Municipal Staff & Financial Considerations	
○	Community engagement
○	Inter-departmental co-ordination
◉	Design team
◉	Capital cost
◉	Operation & maintenance costs

○ Low Effort/Cost ◉ Moderate ● High

Design Considerations	
○	Geotechnical testing complexity
○	Infiltration testing complexity
◉	Planning complexity
◉	Design complexity

○ Low Effort ◉ Moderate ● High

Benefits	
○	Flood risk reduction (water quantity)*
●	Pollutant removal (water quality)
○	Groundwater recharge (water balance)*
○	Stream channel erosion control
○	Amenity & aesthetic value
○	Traffic calming
○	Urban tree canopy
○	High profile with community & media

○ Low Benefits ◉ Moderate ● High

*Performance will vary based upon site characteristics and design of LID practice.

2.5 Permeable pavement

Permeable pavement is a term used for a number of LID practices that can be used in place of conventional asphalt or concrete pavement. These alternatives contain pore spaces or joints that allow stormwater to pass through to a stone base where it is infiltrated into the underlying native soil or temporarily detained.

For best results in ROW applications, permeable pavement should be limited to areas subject to light vehicle traffic, including parking lay-bys, shoulders, cycle paths, and pedestrian areas. Permeable pavement is suitable for curb-to-curb installation on local minor residential roads. Use in heavier traffic areas is not recommended—these materials don't currently wear as well as conventional asphalt or concrete.

Different types of permeable pavement are described below.

Porous asphalt

Porous asphalt is very similar to conventional hot-mix asphalt, but it has a significantly reduced percentage of sand and fines, encouraging the formation of stable, interconnected air pockets. The pockets allow stormwater to filter to the underlying aggregate layer and base.

Given the need for the appropriate underlying infrastructure, permeable pavement cannot be incorporated into road resurfacing projects. These BMPs are best suited for road reconstruction projects. As all three types of permeable pavement share this similar base infrastructure, they each provide the same level of stormwater treatment. Selecting the appropriate pavement material will depend upon factors like local availability and contractor experience.

Due to the potential for clogging, using porous asphalt for roadways where sand is used for snow or ice treatment is not recommended. Like pervious concrete, porous asphalt requires modified application and setting. It can be a durable and cost competitive alternative to conventional asphalt.

Pervious concrete

Like conventional concrete, pervious concrete is primarily comprised of Portland cement, open-graded course aggregate, and water. Pervious concrete, however, contains less sand and fines than conventional concrete, creating void spaces in the material allowing stormwater to filter to the underlying aggregate layer.

The surface texture of pervious concrete is slightly rougher than conventional concrete which provides additional traction for vehicles and pedestrians. This additional traction, combined with less standing water on the surface of the concrete, results in reduced sanding and salting requirements.

Permeable concrete can be a durable and cost-competitive alternative to conventional pavement options.

Figure 2.5.1: Porous asphalt and other permeable pavement materials have been used extensively in alleyways and other low-traffic applications in Chicago, IL and Philadelphia, PA (Source: Aquafor Beech)

Figure 2.5.2: Porous asphalt was used to create a permeable bike lane in Edmondston, MD. As pervious asphalt can look quite similar to traditional asphalt, municipalities should track the location of permeable infrastructure to ensure that it is not re-paved in future roadwork. (Source: CVC)

Figure 2.5.3: Pervious concrete requires a modified poring and setting approach when compared to standard concrete. Porous concrete was used to create a permeable parking lay-by in Streetsville in Mississauga. (Source: CVC)

Permeable pavers

Permeable pavers have large joints that are filled with a porous aggregate material. Like porous asphalt and pervious concrete, crushed stone aggregate bedding under the permeable pavement supports the pavers and provides storage for stormwater retention, infiltration and treatment.

An advantage of pavers is the improved aesthetics made possible by varying colour and pattern. Among other uses, they can help differentiate parking lanes from the travel portion of the roadway and highlight pedestrian crossings.

When considering retrofitting with permeable pavement, it is important to examine current use of the prospective site. For instance, use of pavers in a designated or informal smoking area can result in reduced aesthetics from cigarette butts accumulating in paver joints. In this instance, it's good to have a plan for regular cleaning and maintenance.

Suitability	
●	High density
●	Medium density
●	Low density

○ Low Suitability ◎ Moderate ● High

Municipal Staff & Financial Considerations	
◎	Community engagement
○	Inter-departmental co-ordination
◎	Design team
●	Capital cost
◎	Operation & maintenance costs

○ Low Effort/Cost ◎ Moderate ● High

Design Considerations	
●	Geotechnical testing complexity
●	Infiltration testing complexity
◎	Planning complexity
●	Design complexity

○ Low Effort ◎ Moderate ● High

Benefits	
◎	Flood risk reduction (water quantity)*
◎	Pollutant removal (water quality)
●	Groundwater recharge (water balance)*
●	Stream channel erosion control
○	Amenity & aesthetic value
○	Traffic calming
○	Urban tree canopy
◎	High profile with community & media

○ Low Benefits ◎ Moderate ● High

*Performance will vary based upon site characteristics and design of LID practice.

Figure 2.5.4: Permeable pavers can be used to create visual interest within the ROW. On Elm Drive, located in Mississauga, permeable pavers with different shapes and colours were used for parking lay-bys and the sidewalk. (Source: CVC)

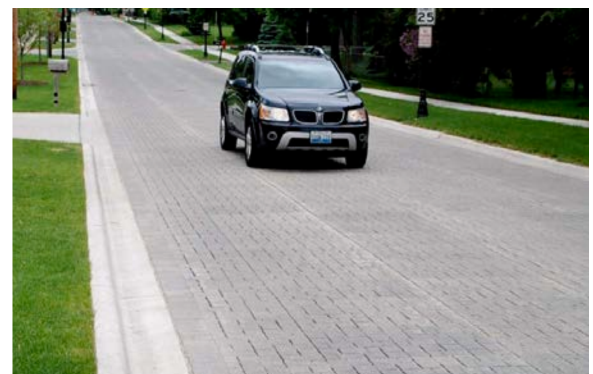


Figure 2.5.5: Permeable pavers can be used in a curb-to-curb application, as shown in this example from Warrenville, IL. Using pavers within the road or along the parking lanes helps with traffic calming. (Source: ICPI)

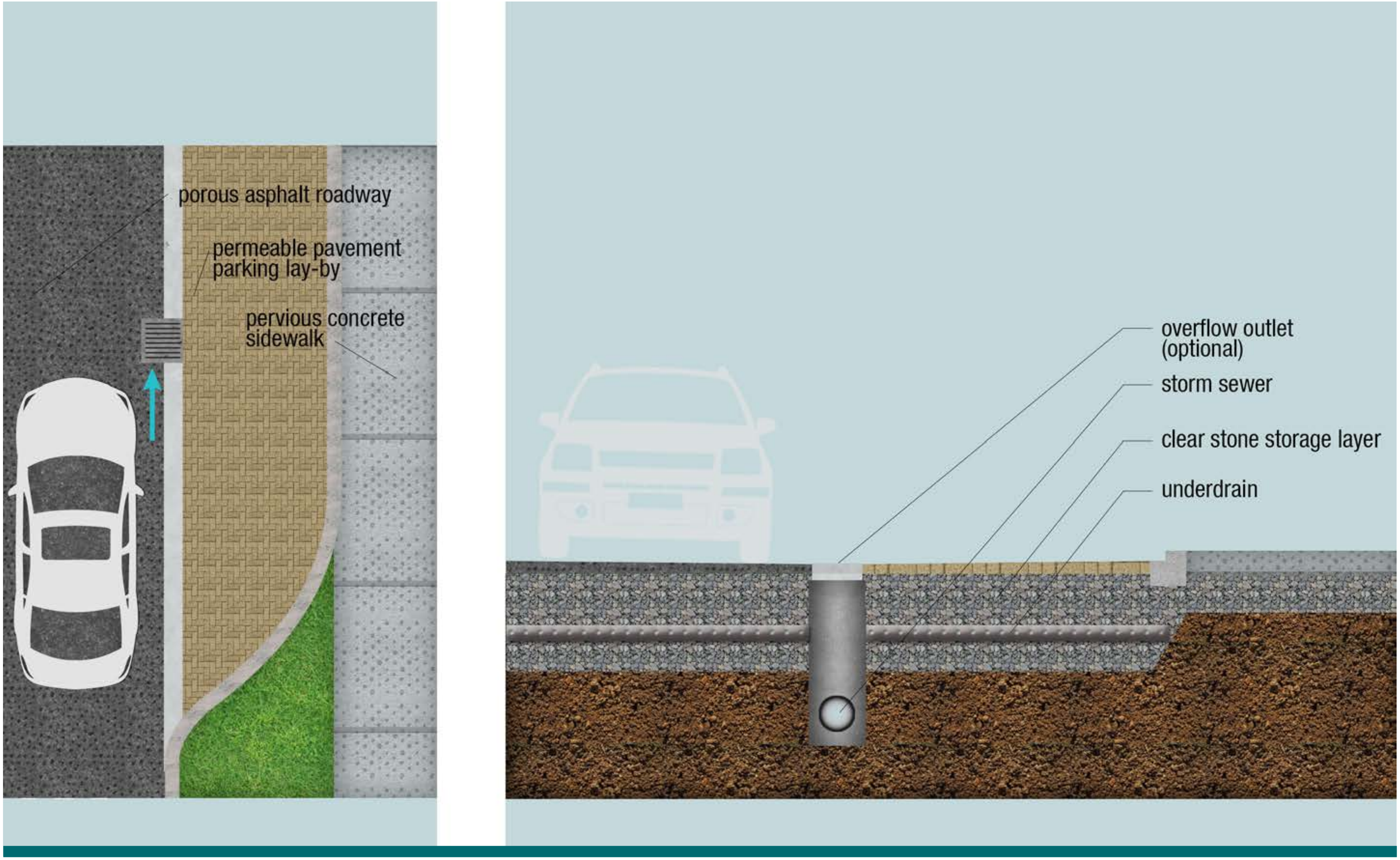


Figure 2.5.6: Permeable pavement plan view [left] and cross-section [right] showing porous asphalt roadway, permeable pavement lay-by and pervious concrete sidewalk

LID ROW Retrofit Implementation Process

The following is a quick over-view of the 10 steps involved when implementing an LID ROW retrofit. You can use this as a quick reference or check list to make sure your project is staying on track

Each step can be broken down into the following three categories:

Key Activities

These actions must be completed for your LID project to move forward.

Project Team Members & Expertise

A list of which teams members you will require to complete each step.

Key Considerations

A few key details that you should keep in mind during each step of your retrofit.

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Building the Project Team

- [ ] Identify core and support project team members and at which project phases their expertise will be required.
- [ ] Develop an RFP and hire an experienced consultant.

- [ ] Project Manager

- [ ] Look ahead to future phases of the project to determine what team members will be required. Consider the skill sets and expertise that are available within your municipality.

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Background Review

- [ ] Screen the LID options based on; type of construction project, type of ROW cross-section, cost, and site specific criteria
- [ ] Evaluate all options using direct and indirect project costing table

- [ ] Civil/Environmental/Water Resources Engineer
- [ ] Municipal Project Manager

- [ ] Screening should include non-engineering/ technical requirements, multi-disciplinary team is recommended

page 60

Screening the Options

- [ ] Review all relevant background documents from agencies, municipality, and regions.
- [ ] Conduct a site reconnaissance to verify site conditions and identify constraints and data gaps.

- [ ] Civil/Environmental/Water Resources Engineer
- [ ] Municipal Planner/Project Manager

- [ ] Thorough background review can provide future project cost savings.

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Pre-design

- [ ] The pre-design phase includes the collection of field measurements which builds upon information gathered during the field reconnaissance and background document review

- [ ] Civil/Environmental/Water Resources Engineer
- [ ] Hydrogeologist
- [ ] Ecologist/Biologist

- [ ] Conduct public consultation process to present alternatives and identify community needs

page 89

Detailed Design

- [ ] Review LID Stormwater Planning and Design Guide Version 1.0 (TRCA/CVC 2010) for guidance.
- [ ] Develop detailed design drawings

- [ ] Civil/Environmental/Water Resources Engineer
- [ ] Agencies
- [ ] Landscape Architect
- [ ] Hydrogeologist
- [ ] Ecologist/Biologist
- [ ] Project Manager
- [ ] Product Suppliers

- [ ] Conduct public consultation process to present preferred alternative. Consultation with agencies should be considered at this phase

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Approvals

- [ ] Review municipal, Provincial, Federal and agency policies and local by-laws
- [ ] Identify application processes for obtaining approvals

- [ ] Civil/Environmental/Water Resources Engineer
- [ ] Municipal Planner/Project Manager
- [ ] Ecologist/Biologist
- [ ] Agencies

- [ ] Pre-consult with approvals agencies so there are no surprises during the approvals phase

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Tenders & Contract Documents

- [ ] Review detailed design
- [ ] Develop detailed cost estimates, schedule of items, and contractual documents
- [ ] Develop tender package for submission

- [ ] Civil/Environmental/Water Resources Engineer
- [ ] Municipal Legal Department
- [ ] Municipal Planner/Project Manager

- [ ] Obtain standard templates from municipality if available and coordinate document review with the municipal legal and purchasing departments

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Construction Supervision & Administration

- [ ] Supervise work of contactor and provide guidance as necessary
- [ ] Document site activities and maintain client relations

- [ ] Civil/Environmental/Water Resources Engineer
- [ ] Product Suppliers
- [ ] Municipal Planner/Project Manager
- [ ] Landscape Architect

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Lifecycle Activities

- [ ] Review operation and maintenance requirements
- [ ] Provide municipality with guidelines detailing short and long term operation and maintenance strategies

- [ ] Civil/Environmental/Water Resources Engineer
- [ ] Municipal Planner/Project Manager
- [ ] Product Suppliers
- [ ] Landscape Architect

- [ ] Undertake periodic inspections to determine general operation and maintenance needs

3.0 Building the Project Team & Consulting the Public

Large-scale ROW retrofit projects that cross municipal or provincial boundaries can require municipal staff, councillors, regional councillors, conservation authority staff, provincial staff and consultants at the table.

Unlike stormwater management features like stormwater ponds that can be isolated or fenced off, LID ROW retrofits are directly integrated into the existing urban form. As such, it is important to consider how the project will affect all users of the ROW. Though the ROW is often seen as a transportation corridor, many other processes that are vital to community function occur in this space. Items to consider include:

- Sidewalks and bike lanes are common along urban cross-sections and can also be found in rural cross-sections
- Storm sewers and sanitary sewers are buried within the ROW
- Utilities such as electrical and communications lines are either strung overhead or buried in trenches within the corridor
- Roads may be within existing or planned public transportation routes which may affect available space for LID featuresAccess to private properties by emergency services including fire trucks must be considered
- Interactions with adjoining land uses
- O&M considerations, including road operations, winter maintenance, parks and forestry services

These variables lend themselves to a multi-disciplinary project team that includes members from various municipal departments, along with external agencies and stakeholders. Additionally, the size and cost of the project may influence external involvement.

Bringing the right project team and stakeholders together in the early stages of the project can lead to synergies, such as costs savings through resource sharing, insights into the proposed site and its social context, funding opportunities, all leading to a greater level of project success. The project team can be divided into two teams: the core project team and the support project team.

3.1 The core project team

Within the LID retrofit process, the core project team's role is to develop an overall plan and provide key information to assist the project manager with decision making, and identify knowledge gaps, staff, external organizations, and stakeholders who can provide information, advice, or professional expertise. The core team should be able to provide support in practical applications with the development of the terms of reference, tender, or request for proposal (RFP), review and comment on site design, and assist in LID construction administration and oversight.

The core project team must include a broad range of professionals with different fields of expertise and perspectives. Members must possess a comprehensive understanding of goals and targets associated with stormwater management and roads construction and operations. To plan sustainably, project members must also understand short and long-term implications of urban development on watershed processes and the resulting impact on the community.

Regardless of the size of the municipality or its location in the province, the core team requires a similar level of expertise for implementation of ROW LID practices. These include:

- Planning
- Engineering (water resources, structural, civil, electrical)
- Landscape architecture, design, and maintenance
- Road works and maintenance

LID practices are designed for long-term functionality. It is vital to include the department that will be responsible for maintenance of your ROW LID feature as part of the core project team. If a proposed LID site does not currently receive a high level of maintenance, it is best to pick an option that fits the current maintenance regime.

Plan Ahead, But Be Flexible: When implementing your first LID projects, it's difficult to estimate the number of meetings you'll need. The Lakeview Project had eight meetings scheduled, but ended up requiring nineteen meetings total (six additional for design and five during the tendering process).

3.2 The project support team

The purpose of the support team is to provide needed information to assist with key decisions and/or a functional role that falls outside the expertise of the core project team. Consider the following areas for your project support team:

- Terrestrial and aquatic sciences
- Geosciences (hydrology, hydrogeology, and geomorphology)
- Transportation or transit services
- Fire and emergency services
- Forestry and parks
- Capital works
- Marketing and communications
- Environmental services and stewardship
- Community services
- Local rate payer associations, business improvement associations, and residents
- Councillors
- Regional government
- Conservation authority
- Provincial staff

Not all of these identified groups have to be part of the project support team; however it is best to engage them early in the planning process to allow them to include or excuse themselves as they see fit.

Table 3.2.1: The Integrated Project Team, provides further guidance for which departments to include specific to certain LID features (see Chapter 4 – Screening the LID Options).

Municipal department	Bioretention (all types)	Perforated pipe	Permeable pavement	Prefabricated module	Enhanced grass swale
Planning	●	●	●	●	●
Engineering	●	●	●	●	●
Roads	●	●	●	●	●
Capital works	●	●	●	●	●
Parks	●	◉	○	◉	◉
Forestry	●	○	○	●	○
Fire and emergency services	●	●	●	●	●
Transportation	●	●	●	●	●
Communications	●	●	●	●	●
Stewardship	●	○	○	○	◉

○ Minimal Input ◉ Support ● Core

3.3 Integrating the design process

As a project progresses through the planning, design, construction, O&M, and monitoring phases, the requirements and necessary team members will change. Site-specific criteria will determine the extent of the required help from the core and support project teams. To ensure decisions are made based on a comprehensive understanding of the functions, processes and requirements of the watershed, subwatershed, neighborhood and site, additional project expertise may be required.

Need some help? Feel like you don't have the expertise at hand? Hiring qualified and experienced consultants along with working with your local conservation authority can provide the help you need. Visit CVC's Be a Leader website at:.

bealeader.ca

3.4 Bringing the right consultant onto the team - the RFP process and consultant selection

LID is an emerging field in Ontario. Successful projects will help build confidence in the approach, particularly when LID projects are in the public realm. Hiring the right consultant to be an integral part of the project team can provide great value and make all phases of the project more successful. The first step toward choosing the right consultant is to issue a comprehensive project bid solicitation document.

Request for Quotation (RFQ), Request for Proposal (RFP) and Expression of Interest (EOI) Processes

LID retrofit projects present challenges and requires skill sets beyond the scope of conventional roads projects. For road construction projects, municipalities sometimes opt to use a Request for Quotation (RFQ) instead of a Request for Proposal (RFP). A RFQ requires consultants to bid on specific services and deliverables. Creativity is limited, since most specifications are provided in the request, and the winning bid often has the lowest cost. LID projects are relatively new to Ontario, and the consulting industry lacks experience with LID retrofit projects within the municipal ROW. These projects often require additional technical requirements and design flexibility. For these reasons, an RFQ is not suitable.

Table 3.4.1: Approaches to consultant selection.

Approach	Description	Advantages	Disadvantages
Request for quotation (RFQ)	A request for consultants to provide costs for specific items and project deliverables based on design standards provided by the municipality.	• Appropriate for common infrastructure repairs and upgrades • Easy selection process focused on cost • Low effort	• Detailed municipal standards required • No room for design flexibility or innovation • Not suitable for LID retrofit project or pilot projects
Request for proposal (RFP)	A request for consultants to provide a proposal outlining their understanding of the project, their proposed project team, potential design or design options, schedule, and costs.	• Appropriate for LID projects • Allows design flexibility and innovation • Can be open to all interested consultants or a select list • Can include pre-qualifications	• Best submission not always the least expensive • Requires a detailed understanding of project constraints and criteria relayed to consultants by municipal staff
Expression of interest (EOI)	A request for consultants to provide information about credentials, experience, and relevant project experience.	• A Two-stage process: EOI followed by a detailed proposal • Easy for municipalities with limited resources • Helps gauge consultant experience in the LID field • Enhances municipal understanding of options • Can be used as a pre-qualification requirement for proposals	• Longer process than directly submitting RFP • Difficult to get responses without making a pre-qualification • Could lead to expanded search of non-local consultants

RFQs should not be used for LID ROW retrofit projects because:

- The project will require design flexibility from planning through the construction phase
- There is a lack of LID ROW retrofit project experience within the engineering consultanting industry

Because they don't include design specifications, RFPs allow consultants more flexibility in submissions. When writing an RFP, be sure to explicitly state the project constraints, criteria, and goals for functionality and final appearance. Depending on municipal policy, RFPs can be open to all interested consultants or delivered to a select list based on relevant experience, reputation, and background research. Depending on policy, it can also be possible to sole source the project. For the purposes of comparison and analysis, all responses should maintain a common structure, and consultants should submit photos of their similar projects.

The structure of a RFP for a LID retrofit project will share elements with RFPs for conventional roads projects. Proposals typically include:

- Project background
- Project team
- Schedule
- Cost of services
- Value added
- References

For pilot projects, consider issuing an EOI request prior to developing a RFP. To motivate consultants, consider using an EOI submission as a qualification for submitting a RFP.

For municipalities lacking LID project experience or undertaking their first pilot project, determining the appropriate practices for ROW retrofits and finding the right consultant can be difficult. In these cases, issuing an EOI prior to an RFP makes sense. With EOI requests, consultants are required to prove their level of understanding of LID projects without getting into design specifics. Responses should include information on credentials and relevant project experience. The EOI process will help the municipality develop an understanding of available project options and ultimately assist in writing a RFP.

Choosing the right consultant

The number of consultants with experience working with LIDs in a ROW setting is limited. When determining which consultant is right for your project, look at the level of experience. Municipalities may consider pre-qualifying consultants based on experience and training. Examples of pre-qualification requirements include, but are not limited to:

- Minimum of one LID ROW project successfully completed
- Completion of Interlocking Concrete Pavement Institute (ICPI) training (for projects involving permeable block pavers)
- Completion of Canadian Standards Association – Sustainable Stormwater Practices Training
- Membership with Consulting Engineers of Ontario
- Membership with Landscape Ontario (for projects involving bioretention and bioswales)
- Certification as an Inspector of Erosion and Sediment Control (CISEC)
- Landscape Architect
- Site Supervision

As part of the consultant selection process, include an interview stage in the RFP for shortlisted consultants to provide an additional opportunity for questions and clarifications.

Consider adjusting the proposal evaluation process for LID projects to favour experience over cost. The most inexpensive proposal is not always the best.

Project components to include in LID RFPs

Implementing a LID retrofit on a road ROW is a complex process, and consultants should be aware of all project components. The type of road construction project planned as part of the retrofit will dictate the required level of effort from the consultant. For example, road resurfacing projects incorporating LID features such as bioretention curb extensions will likely require less effort than incorporating bioretention into a road reconstruction in many categories. Elements to include in an RFP include:

- Background materials
- Infiltration testing
- Geotechnical investigation
- Site inventory
- Topographic survey
- Site hydrology
- Site hydraulics
- Design parameter and constraints determination
- Public consultation
- Preliminary site design
- Detailed design calculations
- Detailed design drawings
- Design brief
- Tender document
- Construction quantities and cost estimating
- Bid response and analysisConstruction contract administration and construction supervision
- As-built drawings

Project components often overlooked in RFPs

When developing a RFP, it is important to include key components that are often overlooked, such as:

- Inclusion of a design brief
- Additional budget for public consultation
- Experienced full-time LID construction supervision and as-built drawings

Design brief

A design brief that focuses on objectives and outcomes is a basic but critical component of any engineering project. LID retrofits of ROWs have goals ranging from stormwater targets to neighbourhood aesthetics. Design briefs should include these objectives, along with the project background, technical information, and detailed calculations. The design brief should accompany any review submissions and approvals applications.

Public consultation

When compared to a conventional road project, LID retrofits of the ROW can require substantial time, effort, and materials associated with public consultation. For example, retrofits planned for residential roads or high density commercial streets might require more public consultation than a retrofit planned for an industrial road. When developing a RFP, municipalities should have an understanding of the level of public consultation effort required for the project and relay this through the RFP document, including a request for additional related budget items. These items can influence the public consultation budget:

- Type of road project
- Construction timing
- Neighbourhood characteristics and demographics
- Level of public involvement
- Past issues (flooding, parking complaints, traffic accidents, business disruptions)
- Political interest

Plan ahead! Include the appropriate level of public consultation within the RFP, the schedule, and the budget

Construction supervision and as-built drawings

Municipalities implementing LID practices frequently overlook construction supervision and project administration. These services are essential; they can help answer questions and make quick decisions. A construction supervisor/administrator with LID project experience is essential. Be sure to outline all construction supervision requirements in the RFP.

LID practices implemented on municipal ROWs will likely need minor design modifications based on unexpected site constraints encountered during the construction phase (see Chapter 9 – Construction Supervision and Administration). Since they are essential for long-term project records and future repairs, it's a good idea to include as-built drawings in the RFP.

3.5 Public consultation and engagement

It is important to consider public opinion before implementing an LID practice. Being aware of concerns, information gaps, public supporters, champions, and the level of importance of each design component can help the design process. This information can come from local residents, the business community, ratepayer associations, and politicians. Different LID practices will require different levels of consultation depending on the community's familiarity with the concept.

Information gained from public consultation can help designers tailor the project so they address both local concerns and values of the community. Consultation can help the design team integrate the LID practice into the public landscape. With improved integration the project is more likely to be perceived as a benefit to the streetscape.

Tailoring the design can make the difference when trying to get residents to maintain the LID feature. The Lakeview Project provided residents the option of a grass or planted boulevard bioretention unit. By providing residents this option, they have had the ability to select the type of practice that best meets their desired level of upkeep. This has led to greater ownership of the bioretention units within the ROW.

For more information, check out the Lakeview Project Case Study in Appendix C.

Issues, concerns, and or priorities that often arise from public consultation during LID ROW retrofits include:

- Existing site use
- Parking requirements including driveway access and configuration
- Observed water quality issues
- Support for broader environmental initiatives
- Flooding issues – chronic or acute
- Integration with the existing site and environment
- Desire for improved conveyance
- Aesthetics and property value impacts
- Traffic calming and children safety
- Provision for sidewalks
- Cost of the project
- Parties responsible for maintenance
- Changes to the maintenance regime
- Proposed road width and changes to configurations

Designate a Project Ambassador to be the point person who coordinates timely responses to inquiries and is responsible for the public image of the project.

Public consultation should be part of the planning process, especially during the implementation of demonstration projects. The public consultation process is opportunity to obtain feedback on the proposed designs, educate residents about broader environmental municipal initiatives, dispel myths, and demonstrate how well-designed stormwater facilities can look just as good as or better than conventional landscapes and landscape features. In addition, the public consultation process can be used to outline project expectations including project schedule, construction process and expected disruptions, assumption protocols and maintenance expectations, and partnership opportunities.

Public engagement should not focus solely on the functional aspects of the LID practice. Communities often respond well when engaged on an emotional level. Consider highlighting how the project will enhance the community and how future generations will benefit from a healthy vibrant watershed.

The objective of the consultation program is to consult with interested agencies subwatershed stakeholders, local business owners, and residents early and regularly, during scoping, design, and construction processes. The selected approach should:

- Build and learn from previous initiatives within the municipality, including contact with local residents and stakeholder groups during previous projects and other ongoing municipal initiatives.
- Use various communication techniques to actively engage the public, stakeholders, and agencies, and generate awareness, understanding and meaningful involvement through the process.
- Exceed the consultation and notification minimums generally used during typical road ROW projects.

Table 3.5.1: Why we engage the public

Each ROW site and consultation is unique. Here, the results from public engagement sessions for ROW LID projects in Mississauga, Toronto and Kingston identify different priority issues.			
City	Mississauga	Toronto	Kingston
Priority issues	1. Parking 2. Water quality 3. Environmental protection 4. Prevent flooding 5. Integration with environment 6. Improve conveyance 7.Integration with existing infrastructure 8. Aesthetics	1. Basement flooding 2. Surface flooding 3. Tree preservation 4. Landscaping 5. Road improvements 6. Aesthetics 7. Traffic calming 8. Water quality	1. Flooding 2. Integration with infrastructure 3. Environmental protection 4. Water quality 5. Aesthetics 6. Traffic calming
Other Considerations	• No sidewalks • Cost not important • Same driveway width after construction • Public willing to do maintenance	N/A	• Children safety • Maintain existing road width • Maintain existing sidewalk width and location but replace with new • Public willing to do maintenance

Table 3.5.1 gives a brief overview of the five general objectives for successful public consultation and engagement.

To learn more, check out the Lakeview project case study in Appendix C.

Figure 3.5.1: A common public engagement tool is display boards. These were used for the Lakeview Project. Display boards allow the public to learn at their own pace and ask questions in an informal setting. (Source: Aquafor Beech)

Effective public consultation allows participants to provide input using a variety of means. Consider using questionnaires, comment forms, question and answer sessions and interactive websites for public input.

Table 3.5.2: Five objectives of a successful public consultation and engagement strategy

Public consultation objective	Method to achieve objective
Public education	Define potential problems, address overall objectives, and discuss alternative approaches in a straightforward manner.
Public information	Clearly provide the scope of the project and project milestones at all public meetings and keep all websites up to date.
Opportunity to comment	Provide the opportunity for the public to comment throughout the project. Distribute questionnaires and solicit comments.
Highly visual information and non-technical language	Provide clear printed announcements, graphic displays, and presentations in lay terms.
Traceability	Make all supporting documents available and document the public process to ensure it meets regulatory and municipal requirements.

Public consultation and engagement options

There are many options for public consultation and engagement. In general, the selected approach will depend on the project budget and schedule, the target audience based on the surrounding land uses, the proposed LID practice and construction project type, maintenance requirements, and the municipality's familiarity with the LID ROW retrofit process. If the LID retrofit is part of a Municipal Class Environmental Assessment (EA), public consultation is a requirement. Public consultation and engagement options can include:

- Public open house
- Public tours of past municipal initiatives in the local area
- Public meeting or workshops on the topic of LID practices within the ROW
- Mailed, emailed, or website resources which outlines and describes the project and outlines LID practices within the ROW
- Community events – BBQs, fairs, gala type events

Figure 3.5.2: A notice of road rehabilitation that includes construction dates, project partners, and contact information in Mississauga's Lakeview District. (Source: CVC)

How can municipalities integrate these options into existing public consultation programs or initiatives? As long as objectives and outcomes align, these programs can be municipally or regionally based, public or private organization supported, or part of existing political or recreational events. Pairing with existing programs can result in substantial cost savings and greater reach of the LID specific public consultation and engagement program.

The level of public consultation can vary depending on the scale and status of individual LID projects. Table 3.5.3 provides a summary of the level of effort required for different types of public consultation and related tasks. Prior to determining the level of public consultation, project teams must determine if the Municipal Class Environmental Assessment process must be followed, and, if so, must undertake the level of public consultation required.

Figure 3.5.3: As part of the Lakeview Project, residents had the opportunity to select the type of plant material in front of their property to encourage feelings of ownership. To enhance participation, the project team held a BBQ community event as part of the public consultation process. This photo shows residents selecting plant material for their homes. (Source: CVC)

Table 3.5.3: Summary of public consultation effort

Level of effort	Description of effort	Engagement method	Information presented	Pros and cons
Low	Consultation is limited to public notification	• Construction commencement signage • Letter to residents	General project information related to the management of public services prior to and during construction, parking limitations, commencement and completion date, and the scope of the work.	Pros: • Cost Efficient Cons: • Limited public feedback
Medium	Consultation incorporates more public interaction and feedback	Low effort methods, plus • Public open house(s) • Questionnaires	General project information, plus • A more education-based experience for local residents to gain knowledge of the specific LID features and benefits	Pros: • Opportunity for residents to ask questions and provide feedback • Design can address feedback and local concerns Cons: • Costlier approach than general notification
High	• Consultation goes above and beyond traditional approaches • Used with high-status projects where public support is critical	Moderate effort methods, plus • Community events • Interpretive signage • Involvement of political figures	General project information, plus • Approach strives for full public involvement and aims to provide a emotional and educational experience for residents	Pros: • Political support can help speed up the implementation process • Increased public awareness and engagement • Could lead to additional LID sites Cons: • Costlier approach with staff time and financial resources • Need political buy-in first

4.0 Screening the LID Options

4.1 Background review

During the initial stages of an LID retrofit, it is strongly recommended that a background review be conducted to refine understanding of the site's opportunities and constraints. Sources of background information may include drawings and reports from several municipal departments including roads, capital works, engineering, and planning as well as non-municipal sources, such as conservation authorities, counties, and regions. While a thorough collection of material can require little effort, it can take a lot of time. However, don't underestimate the value of the potential project cost savings that a review might reveal.

Given the wide variety of LID options available, an important step in identifying the LID option(s) best suited to a particular road is to apply a systematic screening process. This process first involves a review of background materials and field reconnaissance, both conducted by core project team members. Armed with this information and feedback through the public consultation process (see sections 3.5-3.8) informed decisions can be made. This section of the guide identifies specific project issues to watch for during site reconnaissance and outlines a screening procedure that will narrow down your LID options

Background information that could help determine project targets and scope technical investigations could include:

- Municipal road sections and profiles
- Construction drawings from adjacent properties
- Servicing drawings (hydro, phone, gas, cable, and other utilities)
- Grading plans
- Stormwater management and drainage reports
- Reports of flooding from adjacent households
- Sump-pump and foundation drain connection information
- Local stormwater management criteria
- Hydrologic models
- Hydraulic models
- Orthophotography and aerial photos
- Surveys
- Local digital elevation model (DEM)
- Surficial soils and geology data
- Geotechnical investigations and reports
- Digital base mapping (GIS) showing roads, buildings, property fabric, watercourses, storm and sanitary sewer infrastructure, and water mains
- Relevant local policies, by-laws and standards
- Standard templates for design drawings and tender document
- Watershed or subwatershed studies

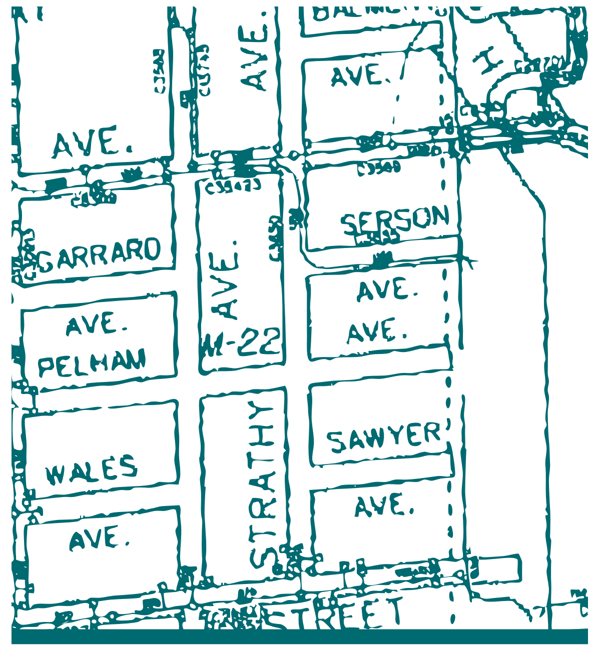

Figure 4.1.1: A vital pieice of background information is storm sewer mapping. This mapping identifies the flowpath of the minor drainage system within the munipcal ROW. (Source: City of Mississauga)

4.2 Field reconnaissance

It is critical that your project team understands the function of adjoining land uses and the activity that occurs in and around your retrofit site. Once an initial desktop assessment of the site is complete, the next step is to conduct field reconnaissance in order to confirm your assessment, determine the technical feasibility of implementing LID practices within the municipal ROW, (i.e., the existing drainage conditions and general ROW characteristics), and identify and confirm any existing constraints.

Site specific constraints and considerations that can be identified during a field visit include:

- Local landscaping features and the landscape aesthetic of surrounding site area
- Overhead or underground utilities
- Utility lines not marked in the drawings
- Traffic patterns or safety concerns - how could the LID practice assist in traffic calming?
- Parking volume and location
- Encroachment issues – are there structures or features, such as fences, present?
- Paved boulevard areas
- Irregular surface drainage patterns, ponding, or lack of conveyance
- Adjoining land use – what activities are present that could impact ROW retrofit design, construction, or maintenance (i.e. excess garbage)?
- Use of the site – do residents use the ROW site to access other amenities, such as a transit shelter?
- Current maintenance practices within the ROW
- Are mature trees present? Could they impact construction, operations, and maintenance of the LID feature?
- Project support –property owners might choose to get involved in LID, but renters might not be inclined

Figure 4.2.1: Go to the site during rainfall to look for ponding water and other opportunities and constraints. (Source: Morrison Hershfield)

Go out in the rain!

Visiting the site during a rain event helps you to understand if there are drainage issues at the site, flow patterns and see other opportunities and constraints.

Figure 4.2.2: Unmaintained property access points that cross the conveyance path of the ROW may not be identifiable on background materials. (Source: Aquafor Beech)

Figure 4.2.3: Encroachments onto the ROW are unlikley to be identified on background materials. In this example, a parking space had been created within the ROW. (Source: Aquafor Beech)

4.3 Screening the options

The choice of ROW LID approach will depend on many factors starting with the type of construction project, type of ROW, and then various physical, social, and economic constraints. This section outlines the typical LID practices for various ROW types and then a list of potential considerations which will help to narrow design options further.

Type of road construction

Opportunities to incorporate LID into ROWs will likely come as a result of planned road works projects including road resurfacing and more extensive road reconstruction. Roadway construction projects are typically phased within a municipality based on infrastructure lifecycle asset management practices and transportation growth plans. Successful and cost effective ROW LID retrofits are best incorporated into road construction projects as is done with other major utility replacements within the ROW. This allows for shared resources such as construction equipment, materials and project staff. It also ensures that the roadway is not closed to the public for additional periods of time. The three most common types of road construction are described in Table 4.3.1 Each type presents different opportunities to incorporate LID techniques into the ROW.

Table 4.3.1: Three common types of road construction defined.

Roadway resurfacing	The grinding of the base and top asphaltic compound to some nominal depth from the existing road surface and allowing for approximately 15-30% spot base repair where required while maintaining the original vertical design of the road. May also include: • Repair or replacement of concrete curb and installation of sub-drains • Repair of concrete sidewalks • Adjustment and/or replacement of driveway aprons and sod
Road reconstruction	Complete removal and replacement of the major ROW elements including the road base and asphalt surface, concrete curb, sidewalks, and can include reconstruction or replacement of the sub-surface infrastructure (hydro, gas, water main, sanitary and stormwater infrastructure). Another type of road reconstruction can include the conversion of a rural cross section roadway into an urban cross section. This typically includes the installation of storm sewers, complete base and asphalt replacement, concrete curb placement, sub drains under curbs, and catch basin placement.
Road improvement from rural to urban cross section	As areas urbanize or infrastructure is upgraded rural cross section streets may be converted to an urban cross-section with curbs, gutters and storm sewers. Upgrades are one of the most common and economical opportunities in which LID can be incorporated into roads.
Roadway reduction	A process in which the effective width or number of travel lanes contained in a cross-section is reduced in order to achieve system improvements. Roadway reductions can be used for traffic calming purposes, transit projects, alternative transportation strategies such as the interdiction of bicycle lanes, and pedestrian crossings. Through the process of roadway reduction, areas of the ROW that were used for vehicular travel are converted to sidewalks, landscaped boulevards, and/or cycle lanes.

LID opportunities and road types

ROW standards in Ontario vary by municipality, but generally there are seven typical ROW types:

- Local residential road
- Residential collector road
- Local industrial road
- Industrial collector road
- Minor arterial
- Major arterial road
- High density commercial road

The characteristics, LID opportunities and constraints, and examples are presented for each of these ROW types on the following pages. Typical LID options for each of these street types are offered. However, this guidance is not intended to be prohibitive of other LID options, but rather to help reduce the number of LID options in the preliminary phases of screening and alert the designer to LID opportunities unique to that road type. Other considerations such as adjacent landuses, traffic demands, utility locations, budget constrains and geological conditions will determine the most appropriate LID solution.

For further guidance on incorporating LID within the ROW, refer to Appendix F - Examples of Municpal Road Sections, Profiles and Standards with LID.

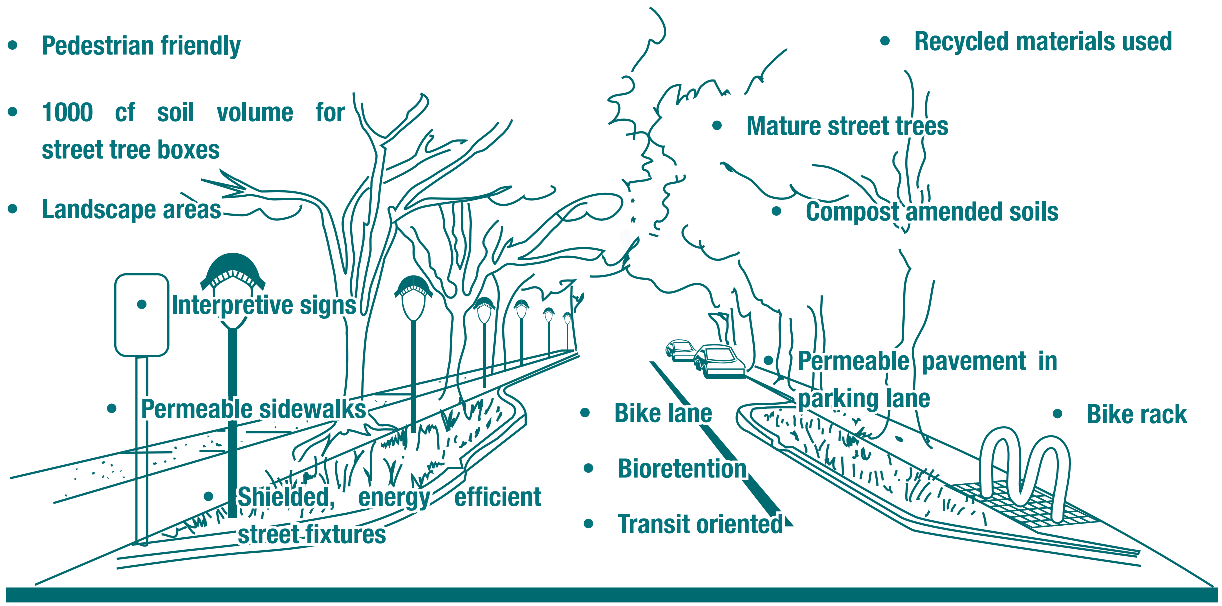

Figure 4.3.1: Anatomy of a Green Street. (Source: Ann English)

Local residential road (rural cross section)

Figure 4.3.2: Local minor residential with rural cross section. (Source: Aquafor Beech)

Local residential streets are the most common street type. They serve as access to the residential lots within those areas created by, or bounded by, thoroughfares, arterials, collectors, and primary residential streets and other physical boundaries such as natural streams and railroads. Since the primary function is local vehicular access rather than intercommunity circulation, theses roads have low traffic volumes and mostly lightweight vehicular traffic, but they must accommodate the rapid access needs of emergency vehicles. Other characteristics specific to the residential rural cross section include:

- Shoulders are grassed, gravel, or bare soil from winter maintenance, pedestrians and street side parking
- Side drainage ditches are often narrow, poorly graded, and can be difficult for homeowners to maintain
- Utilities are often in separate trenches rather than a combined utility trench

Typical opportunities for rural cross section

Within the roadway:

- Use of permeable pavement within the roadway is not economical when there are adjacent swales to filter and infiltrate runoff

Within the boulevard:

- Bioswales or the use of perforated pipes beneath grass swales can reduce the nuissance problems associated with conventional swales like standing surface water and steep slopes
- Permeable pavement systems can be used to stabilize and improve degraded shoulders
- Converting degraded ditches to enhanced grass swales is the simplest LID improvement to make to residential rural cross-section roads. Driveway culverts can be slightly raised to provide storage and encourage infiltration

Figure 4.3.4: While many homeowners of this Toronto neighborhood have kept their enhanced swales as grass, a few have turned their swales into gardens that increase stormwater treatment and infiltration. Note that only low growing vegetation was used to avoid encroach on street corner sight lines. (Source: CVC)

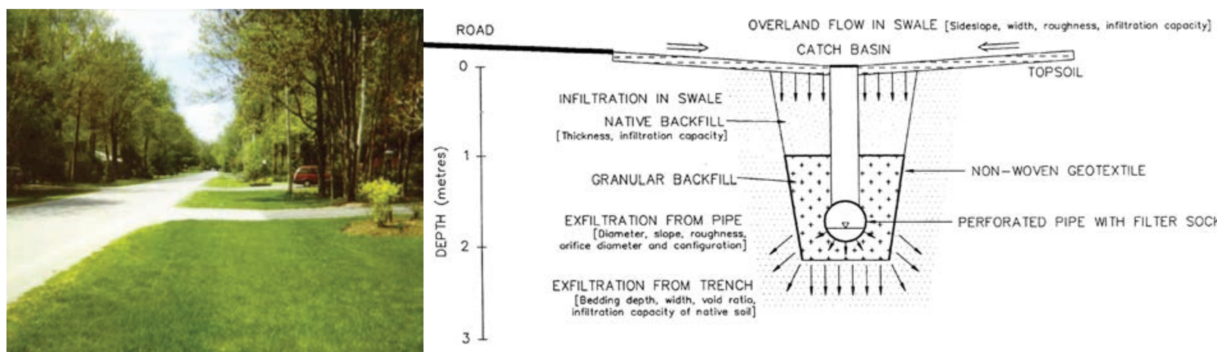

Figure 4.3.3: This perforated pipe beneath a grass swale system in a residential neighborhood of Ottawa has been functioning with very little maintenance for over 25 years. 1500 meters of the pipe was videod in 2006, and minimal deterioration was found. (Source: City of Ottawa)

Table 4.3.2: LID options for the local residential road (rural cross section)

ROW Construction Type	Bioretention planter	Curb extension	Boulevard bioretention	Bioswale	Enhanced grass swales	Perforated pipe	Permeable pavement (sidewalk)	Prefabricated modules
Resurfacing	○	○	Possible Option	Common Option	Common Option	Possible Option	Possible Option	○
Reconstruction	○	○	Possible Option	Common Option	Common Option	Possible Option	Possible Option	○

○ Unlikely Option · Possible Option · Common Option

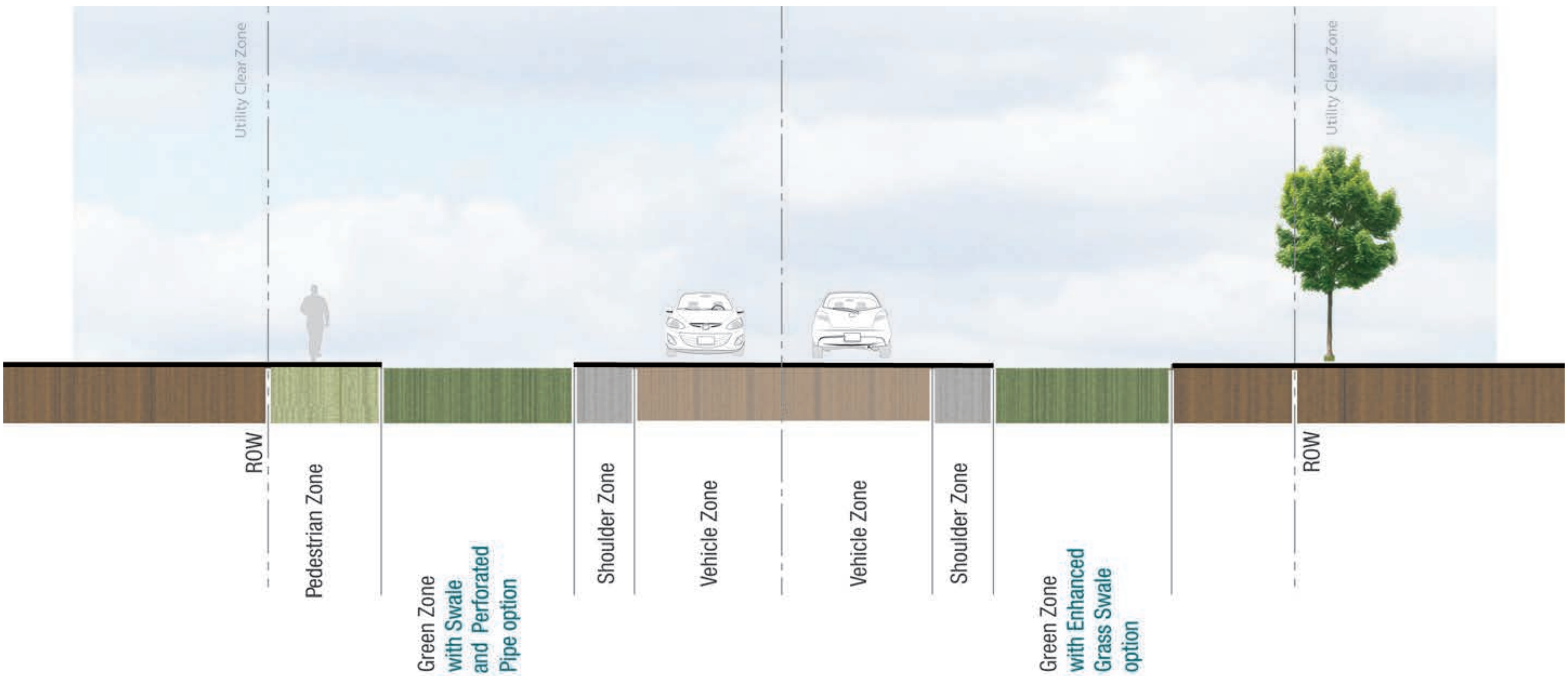

Figure 4.3.5: Cross section of a rural local residential road

Local residential road (urban cross section)

Figure 4.3.6: Local minor residential with urban cross section. (Source: Aquafor Beech)

Local residential streets are the most common street type. They serve as access to the residential lots within those areas created by, or bounded by, thoroughfares, arterials, collectors, and primary residential streets and other physical boundaries such as natural streams and railroads. Since the primary function is local vehicular access rather than intercommunity circulation, theses roads have low traffic volumes and mostly lightweight vehicular traffic, but they must accommodate the rapid access needs of emergency vehicles. Other characteristics specific to the urban cross section include:

- Parking zones are often underused
- Residential boulevard space is the easiest to modify and use for stormwater management compared to other street types
- Utility lines may be in separate or shared trenches

Typical LID opportunities

Within the roadway:

- Curb extension bioretention is a good method for calming traffic and using underutilized parking zones
- Due to low speeds and low traffic, permeable pavement can be used for the roadway from curb to curb

Within the boulevard:

- Boulevard bioretention can be easily incorporated into a rural to urban upgrade by allowing for stormwater treatment within the boulevard space

Figure 4.3.8: Boulevard units installed in Mississauga as part of an upgrade from a rural cross section. (Source: CVC)

Figure 4.3.7: Permeable pavers used from curb to curb in Charles City, IA (left) and New Albany, OH (right). There are many examples of permeable pavement for the full road within cold climate regions of the US. Snow can be ploughted from permeable pavement as with any other pavement. After ploughing remaining snow can melt immediately into the permeable surface thereby reducing the use of deicers. (Source: ICPI)

Table 4.3.3: LID options for the local residential road (urban cross section)

ROW Construction Type	Bioretention Planter	Curb Extension	Boulevard Bioretention	Bioswale	Enhanced Grass Swales	Perforated Pipe	Permeable Pavement (sidewalk)	Prefabricated Modules
Rural to Urban Reconstruction	○	◉	●	◉	◉	●	●	○
Resurfacing	○	●	●	◉	◉	●	◉	○
Reconstruction	○	●	●	◉	◉	●	●	○
Reduction	○	◉	●	◉	◉	●	○	○

○ Unlikely Option ◉ Possible Option ● Common Option

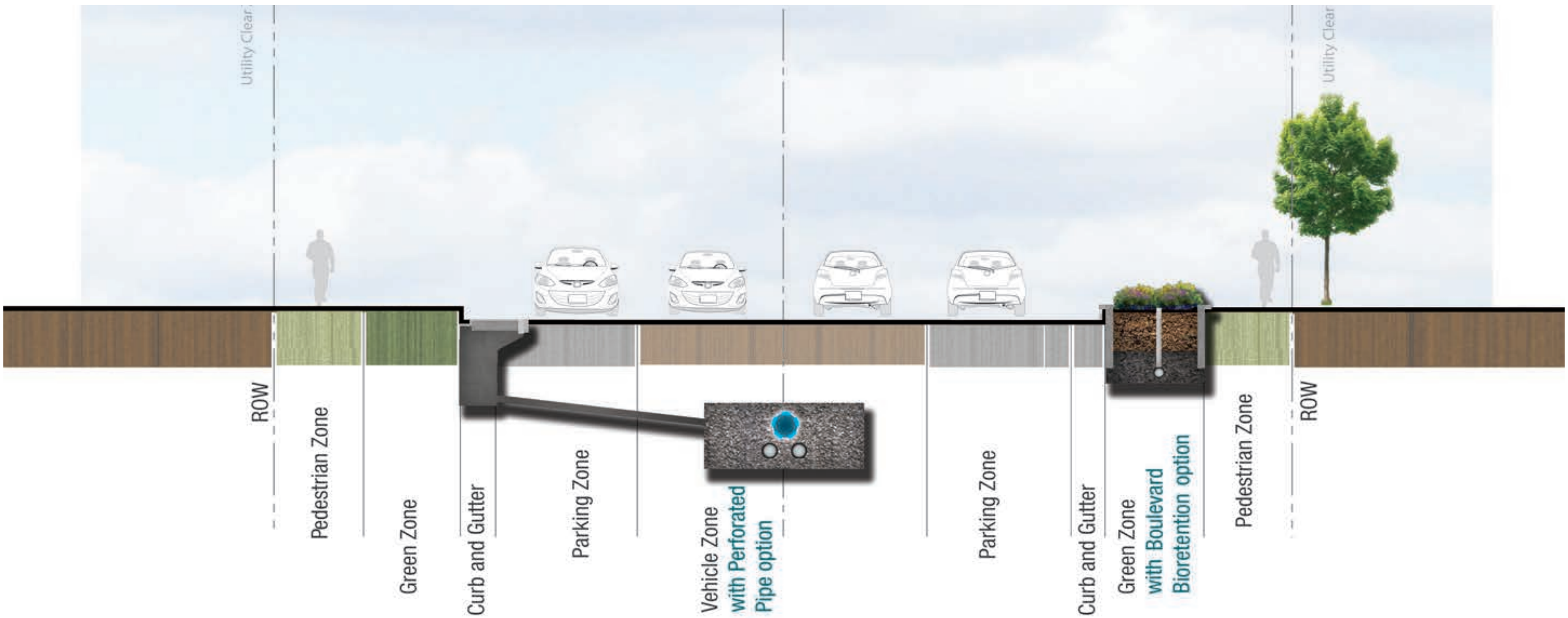

Figure 4.3.9: Cross section of an urban local residential road

Residential collector road

Figure 4.3.10: Local Residential Collector Street. (Source: Aquafor Beech)

The function of these streets is to act as connectors between residential neighborhoods and other collectors and arterials. The character of these streets can vary widely from completely residential to pockets of commercial or mixed use landuses. Other characteristics include:

- Moderate to high traffic volumes, average daily traffic 1500 to 3000 vehicles
- Street parking is atypical unless there are adjacent mixed uses.
- Often have multi-modal use, transit, pedestrian, and cyclists
- Institutions such as schools, recreational facilities, and churches are often located along collectors

Typical LID opportunities

Within the roadway:

- Permeable pavement should be avoided for high traffic travel lanes, but they are an option for parking lanes and sidewalk. Pervious concrete or porous asphalt are options for bike lanes.
- Perforated pipes are suitable for collectors with very limited space and particularly where there is no routine landscaping maintenance. However, adequate pretreatment such as grass swales, extended sump catchbasins, or prefabricated units must be provided.
- Curb extension bioretention is not a common practice for collectors, but they can be used in some cases to reduce pedestrian crossing distances at intersections

Within the boulevard:

- Collectors with few driveway access points and continuous stretches of open boulevard space are good candidates for bioswales
- Institutional uses along collectors offer opportunities for innovative LID solutions. Runoff can be treated within adjacent park space or on school properties where agreements have been made with school boards. These areas are also good opportunities for LID showcases or demonstrations.

Figure 4.3.11: Before and after pictures of a residential collector, Elm Drive West in Mississauga, improved from a rural cross-section with degraded ditch to an urban cross-section with permeable paver parking laybys and sidewalk. The new design eliminated the degraded swales and improved safety for street parking. (Source: CVC)

Figure 4.3.12: Pervious concrete bike lane and sidewalk in, City of Olympia, WA. (Source: City of Olympia)

Table 4.3.4: LID options for the residential collector road

ROW Construction Type	Bioretention Planter	Curb Extension	Boulevard Bioretention	Bioswale	Enhanced Grass Swales	Perforated Pipe	Permeable Pavement (sidewalk)	Prefabricated Modules
Rural Resurfacing	○	○	●	●	●	◎	◎	○
Rural Reconstruction	○	○	●	●	●	◎	◎	○
Rural to Urban Reconstruction	○	◎	●	●	○	●	●	◎
Urban Resurfacing	○	○	●	◎	○	◎	●	◎
Urban Reconstruction	○	◎	●	◎	○	●	●	◎
Urban Reduction	○	○	●	◎	○	●	○	◎

○ Unlikely Option ◎ Possible Option ● Common Option

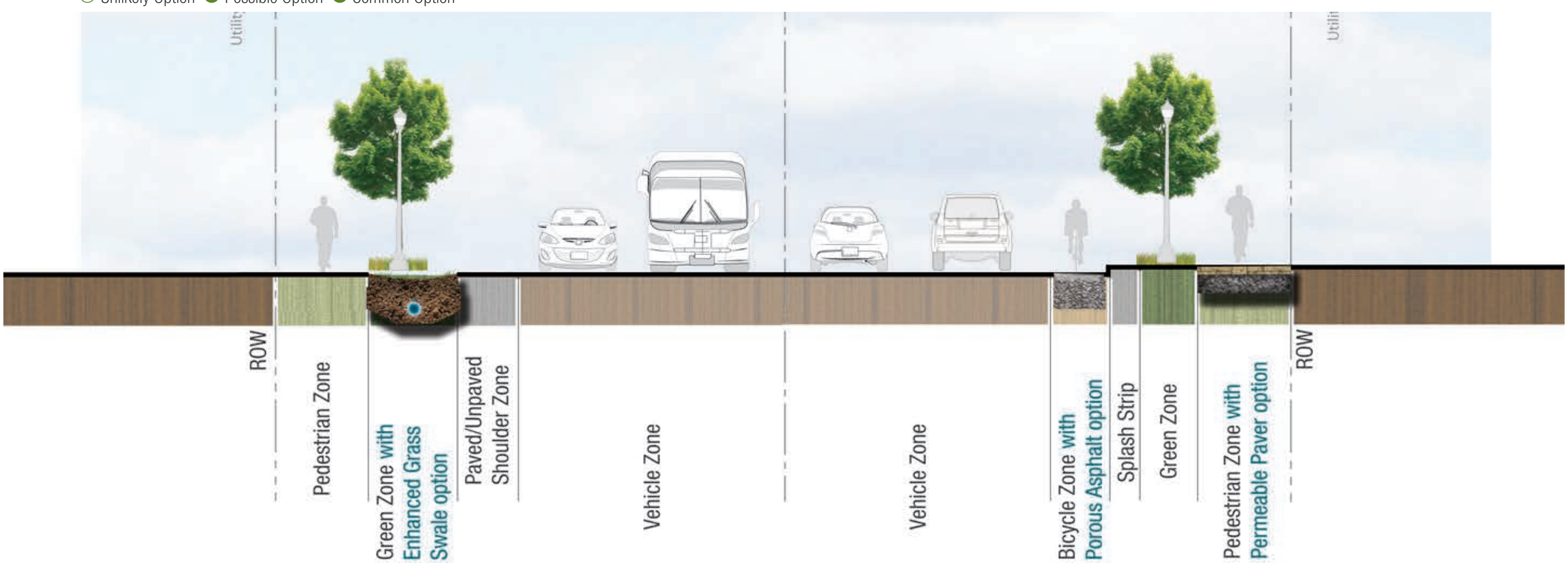

Figure 4.3.13: Cross section of a residential collector road

Local industrial road

Figure 4.3.14: Local industrial road. (Source: Aquafor Beech)

The function of local industrial roads is to provide access to industry and other employment zones. The ability to provide access and easy movement for large vehicles are a primary design characteristic of these types of streets. They are two to three lanes and are not intended for through traffic. Other characteristics include:

- Traffic volumes may be low but the road must still be wide enough to accommodate large vehicle turning movements and have increased structural strength to support heavy loads
- To avoid interference with truck movements landscaping should be low, and trees should be high branching or setback from the roadway
- Boulevards are often wide allowing for swale or other landscape treatment options

Typical LID opportunities

Within the roadway:

- Consideration should be given for wide turning trucks which may encroach on and degrade landscaping or road shoulders. Grid paver systems or widened gravel shoulders near turning areas can be used to accommodate occasional encroachment.

Within the boulevard:

- LID options for local industrial roads will heavily depend on the adjacent industries. For example, bioswales and other filtering practices may clog quickly where heavy industry like concrete mixing plants will track sediment onto the roads. Grass swales with sediment traps or prefabricated oil/grit separators which can be cleaned out on a frequent routine basis would be appropriate. Conversely, bioswales and perforated pipe can work well in areas of light industrial and commercial landuses.

Figure 4.3.15: Prefabricated modules can be used on local industrial roads to capture high sediment loads. (Source: CVC)

Figure 4.3.16: This light industrial and commercial road in Chicago uses permeable pavers from curb to curb and loops around a dry detention feature. (Source: ICPI)

Table 4.3.5: LID options for the local industrial road

ROW Construction Type	Bioretention Planter	Curb Extension	Boulevard Bioretention	Bioswale	Enhanced Grass Swales	Perforated Pipe	Permeable Pavement (sidewalk)	Prefabricated Modules
Rural Resurfacing	○	○	◘	◘	●	◘	◘	◘
Rural Reconstruction	○	○	◘	◘	●	◘	◘	◘
Rural to Urban Reconstruction	○	○	◘	◘	○	●	●	●
Urban Resurfacing	○	○	◘	◘	○	◘	◘	●
Urban Reconstruction	○	○	◘	◘	○	●	●	●
Urban Reduction	○	○	◘	◘	○	●	◘	●

○ Unlikely Option ◘ Possible Option ● Common Option

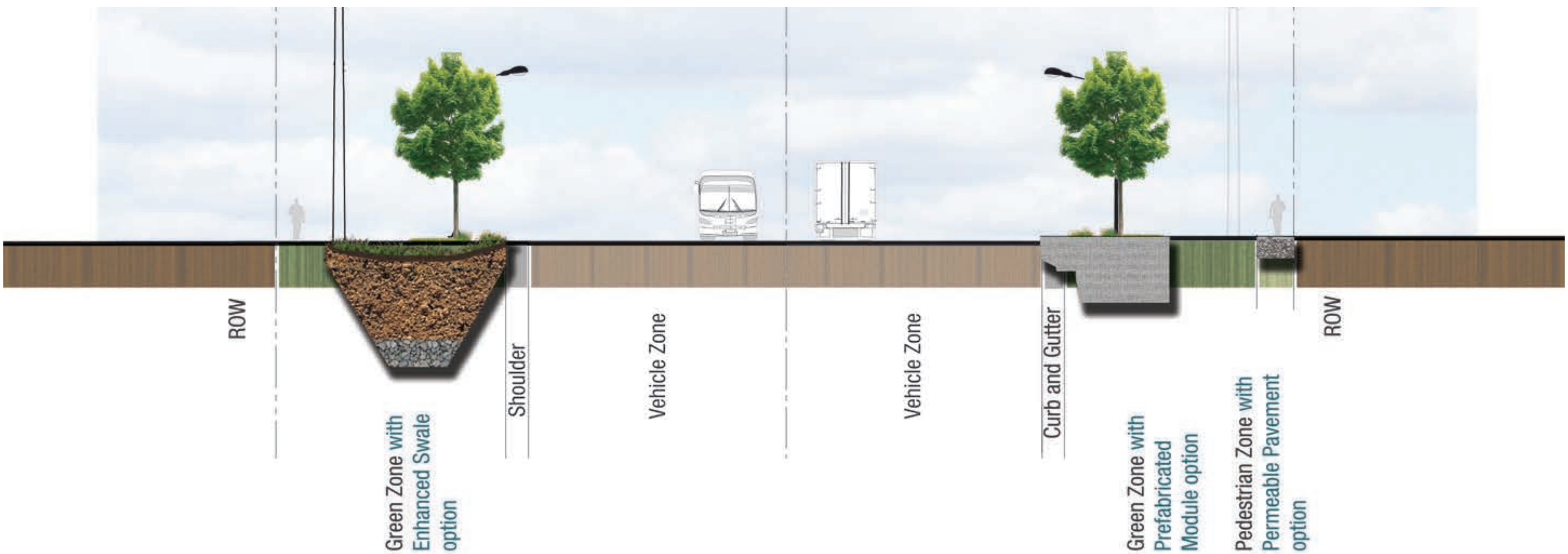

Figure 4.3.17: Cross section of a local industrial road

Local collector road

Figure 4.3.18: Industrial collector road. (Source: Aquafor Beech)

The function of industrial collectors is to provide efficient traffic flow, accomodation for large transport vehicles and access to industry and other employment land areas. These roads are typically four to five lanes and have wide boulevards. Other characteristics include:

- High profile industry is often located along industrial collectors and a high quality corporate landscape treatment is expected
- To avoid interference with truck movements landscaping near roads should be low and trees should be high branching or setback from the roadway

Typical LID opportunities

Within the roadway:

- Due to high traffic and heavy vehicles, LID options within the roadway are limited. Prefabricated sediment traps and perforated pipe with proper pretreatment are potential options.

Within the boulevard:

- Broad enhanced grass swales with perforated pipe can take advantage of wide boulevard spaces
- Any landscape based solutions must consider the landscaping expectations of adjacent properties both with respect to aesthetics and maintenance. Some areas will have an expectation for a simple turf lawn frontage that can be easily incorporated into their maintenance, while other higher profile industrial areas will want distinctive signature landscapes with decorative plantings and shrubs.

Figure 4.3.19: Enhanced grass swale located between the curb and gutter in Washington, DC. (Source: LID Center)

Figure 4.3.20: Grassed bioretention treating road runoff in a wide boulevard space. The grassed bioretention can blend with a corporate property lawn and will be easy for property maintenance staff to maintain with little to no training. (Source: CVC)

Table 4.3.6: LID options for the industrial collector road

ROW Construction Type	Bioretention Planter	Curb Extension	Boulevard Bioretention	Bioswale	Enhanced Grass Swales	Perforated Pipe	Permeable Pavement (sidewalk)	Prefabricated Modules
Rural Resurfacing	○	○	◎	◎	●	◎	◎	◎
Rural Reconstruction	○	○	◎	◎	●	◎	◎	◎
Rural to Urban Reconstruction	○	○	◎	◎	◎	●	◎	●
Urban Resurfacing	○	○	◎	◎	◎	◎	◎	●
Urban Reconstruction	○	○	◎	◎	◎	●	◎	●
Urban Reduction	○	○	◎	◎	◎	●	◎	●

○ Unlikely Option ◎ Possible Option ● Common Option

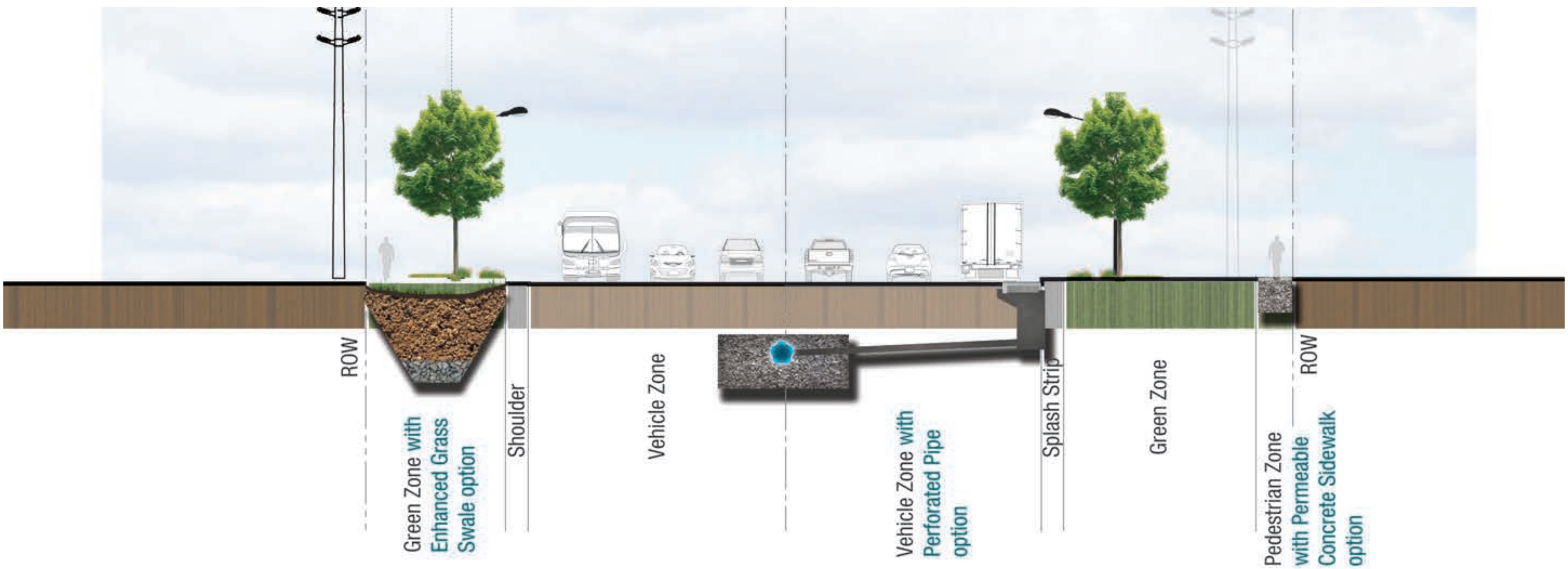

Figure 4.3.21: Cross section of industrial collector road

Minor arterial road

Figure 4.3.22: Minor arterial road. (Source: Aquafor Beech)

Minor arterial roads are automobile oriented roads intended to move high vehicle traffic volumes and are typically four lanes. Pedestrian and bicyclist accommodations are sometimes expected. Other common characteristics include:

- Boulevards are often wide but must accommodate sidewalks on both sides, street trees and splash pads
- May include narrow medians, but runoff is typically directed away from them to road sides

Typical LID opportunities:

Within the roadway:

- Dedicated parking lanes or parking lay-bys can be converted to permeable pavers. The permeable parking lane can be designed to accept only the rainfall that falls on it or it can take runoff from up to two additional lanes.

Within the boulevard:

- Attractive bioretention planters and permeable paver sidewalks are appropriate for high density areas and where business districts expect an enhanced or signature streetscape.
- Street trees can be supported with LID options by providing root volume space in bioretention practices or with sidewalk support systems. Permeable sidewalks allow air and moisture to reach tree roots which in turn reduces sidewalk buckling from roots pushing through the surface.

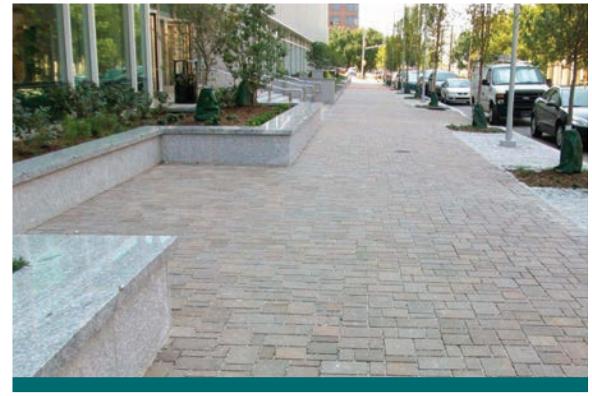

Figure 4.3.24: Permeable paver sidewalk along a minor arterial in Raleigh, NC. (Source: Fred Adams Paving)

Figure 4.3.23: Boulevard bioretention (left) treating runoff from a minor arterial in Washington, DC. (Source: LID Center). Bioretention planters (right) along a minor arterial in Bridgeport, CT. (Source: Tavella Design Group)

Table 4.3.7: LID options for the minor arterial road

ROW Construction Type	Bioretention Planter	Curb Extension	Boulevard Bioretention	Bioswale	Enhanced Grass Swales	Perforated Pipe	Permeable Pavement (sidewalk)	Prefabricated Modules
Rural Resurfacing	○	○	◎	◎	●	◎	◎	◎
Rural Reconstruction	○	○	◎	◎	●	◎	◎	◎
Rural to Urban Reconstruction	●	○	◎	◎	○	●	●	●
Urban Resurfacing	○	○	◎	◎	○	◎	◎	●
Urban Reconstruction	●	○	◎	◎	○	●	●	●
Urban Reduction	●	○	◎	◎	○	●	◎	●

○ Unlikely Option ◎ Possible Option ● Common Option

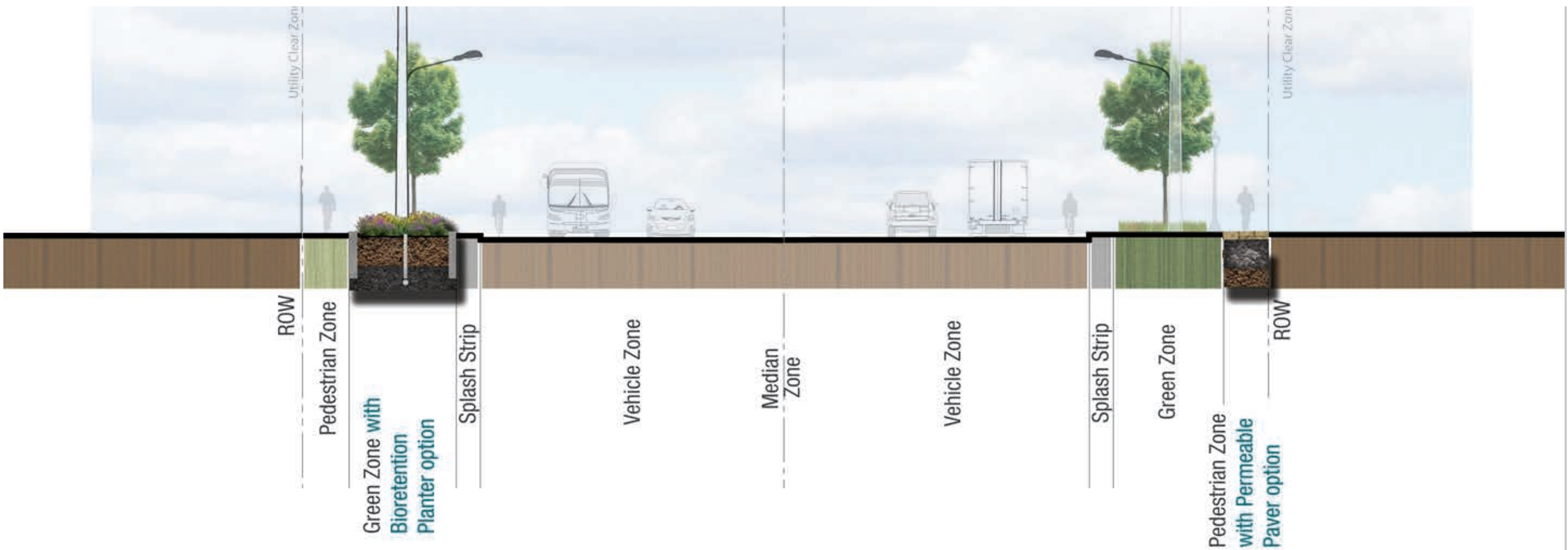

Figure 4.3.25: Cross section of minor arterial road

Major arterial road

Figure 4.3.26: Major arterial road. (Source: Aquafor Beech)

Major Arterials are broad, four to six lanes, with an emphasis on speed, high volume vehicle flow and little on pedestrian or bicycle accommodation. Other characteristics include:

- Wide boulevards and large landscaped medians are common
- Due to higher travel speeds, maintaining clear zones and sight distances are critical

Figure 4.3.27: This large bioretention planter along an urban arterial replaced a large unused expanse of asphalt. (Source: Nevue Ingan Associates)

Typical LID opportunities:

Within the roadway:

- Where possible, replace unnecessarily paved areas such as medians or traffic islands with pervious areas. If road grading allows, than these areas can be converted into treatment practices for surrounding impervious areas
- If the road is double crowned, then medians are an excellent place to treat arterial runoff with a simply landscaped bioretention or bioswales
- If road grades direct no runoff to the median, then reducing the median width and increasing the boulevard space would open more area for stormwater treatment along the side of the roads where the runoff drains
- Getting plants to survive may be difficult in narrow medians, consider decorative permeable paver solution over simply covering them with impervious asphalt or concrete

Within the boulevard:

- Bioretention planters are appropriate for high profile urban arterial roads, but they must be properly designed to handle flows from larger impervious areas and have easily cleaned pretreatment

Figure 4.3.28: Bioswale incorporated into the median of an Arterial Road in Adelphi, MD. The plantings were kept to two or three attractive yet low maintenance plant species. (Source: Low Impact Development Center)

Table 4.3.8: LID options for the major arterial road

ROW Construction Type	Bioretention Planter	Curb Extension	Boulevard Bioretention	Bioswale	Enhanced Grass Swales	Perforated Pipe	Permeable Pavement (sidewalk)	Prefabricated Modules
Rural Resurfacing	○	○	◉	◉	●	◉	◉	◉
Rural Reconstruction	○	○	◉	◉	●	◉	◉	◉
Rural to Urban Reconstruction	○	○	◉	◉	○	●	●	●
Urban Resurfacing	○	○	◉	◉	○	◉	◉	●
Urban Reconstruction	●	○	◉	◉	○	●	●	●
Urban Reduction	●	○	◉	◉	○	●	◉	●

○ Unlikely Option ◉ Possible Option ● Common Option

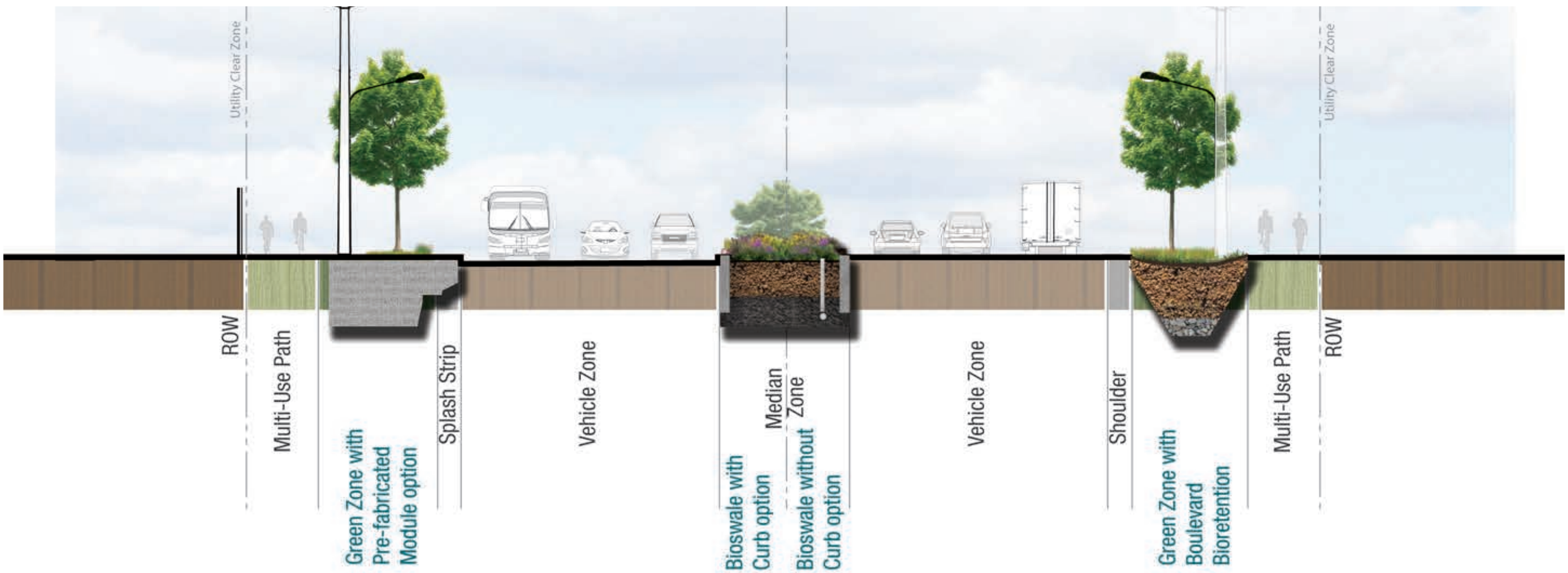

Figure 4.3.29: Cross section of major arterial road

Main streets

Figure 4.3.30: High density commercial road. (Source: Aquafor Beech)

Main streets are set in areas with high density commercial, residential, and mixed use and are typically focal points of the community. The buildings have small to no setbacks and create a continuous wall along the street. They offer an opportunity to incorporate beautifying green infrastructure, but they are also a challenge for designers owing to the multiple demands of street parking, street trees, business access, above and below ground utilities, pedestrian accommodations, and vehicle movement. Depending on age and prominence these streets may have been reconstructed multiple times and have infrastructure legacy issues like abandoned utility lines. Other characteristics include:

- Street parking is typical and may have frequent turn over and is necessary for local business.
- ROW dimensions will vary greatly depending on the age of the community.

Typical LID opportunities:

Multifunctional LID practices are favored where there is a premium on space. Bioretention planters can serve as both the landscape amenity of the street and treat stormwater. Permeable pavement serves as a treatment practice but is also a hardscape for parking and pedestrians.

Within the roadway:

- Curb extension bioretention can be used as traffic calming features and reduce pedestrian crossing distances.

Within the boulevard:

- Due to the high profile of this street type, they are maintained on a frequent basis and provide the most appropriate setting for an aesthetic bioretention feature.
- Street trees are high priorities for this road type and LID options should support or incorporate them by providing root volume space in bioretention practices or with sidewalk support systems.

Figure 4.3.31: City of Kitchener incorporated bioretention planters into their main commercial street, King St. The design incorporates seating and trench drains with decorative grating to take runoff from the street. (Source: CVC)

Figure 4.3.32: If grades necessitate a deep bioretention planter, then appropriate fencing should be provided around the planter as was done in this example from Lansing, MI. The Lansing design also incorporated street trees into the planters. (Source: CVC)

Table 4.3.9: LID options for main streets

ROW Construction Type	Bioretention Planter	Curb Extension	Boulevard Bioretention	Bioswale	Enhanced Grass Swales	Perforated Pipe	Permeable Pavement (sidewalk)	Prefabricated Modules
Urban Resurfacing	○	○	○	○	○	○	◉	●
Urban Reconstruction	●	●	○	○	○	●	●	●
Urban Reduction	●	●	○	○	○	●	●	●

○ Unlikely Option ◉ Possible Option ● Common Option

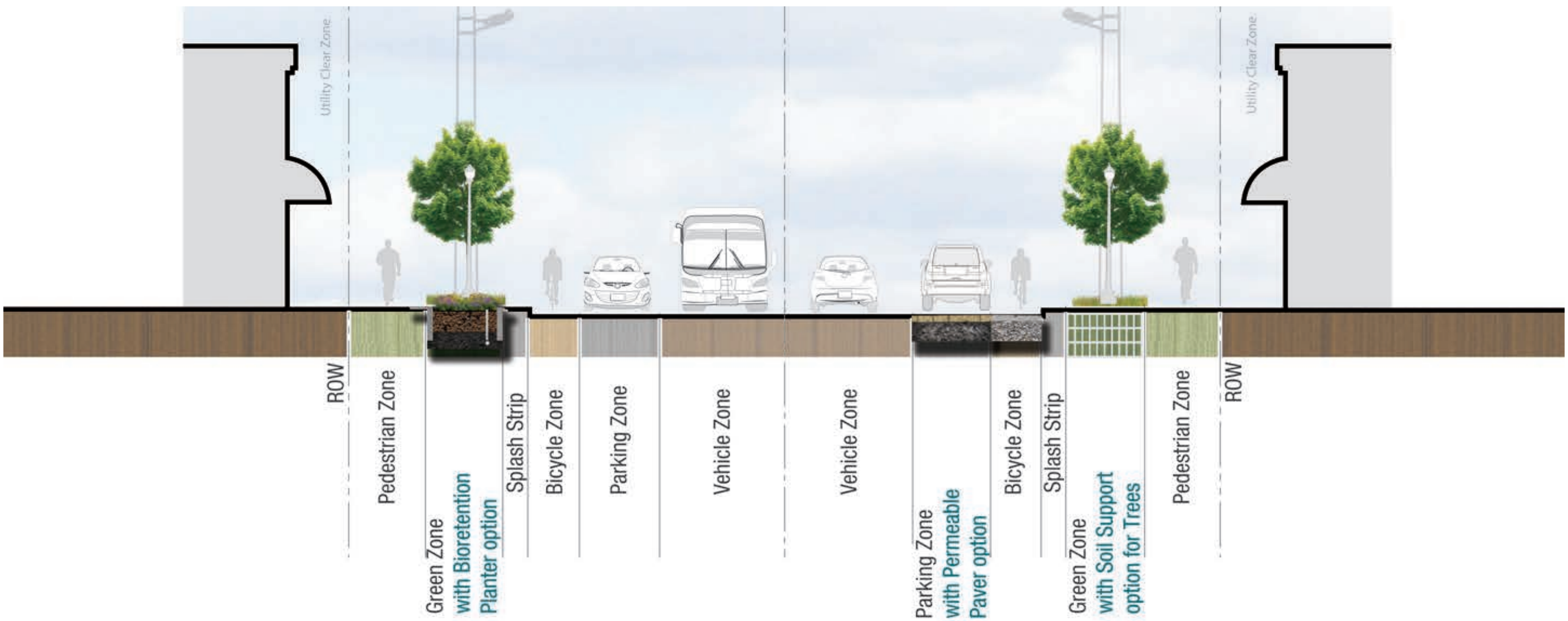

Figure 4.3.33: Cross section of main street

Other design considerations

The previous section presented the most common options based on the type of construction and the road type. The project team must use the information gathered through the background review (Section 4.1), field reconnaissance (Section 4.2), feedback gained from the public engagement (Section 3.5) as well as from the LID practice Suitability & Considerations Comparison Table (Section 2.6) to determine the feasible and optimal LID options for the site. Below is a list of factors to be considered when choosing the type of practice and how it will be incorporated into the site:

Relevant stormwater criteria – compliance with high level municipal and agency documents (i.e. Subwatershed study, master drainage plan).

Site users – who are the users and how will they use the site in future (i.e. are pedestrians using this street to access other services such multi-use pathways, bus routes, commercial areas).

Surrounding land use – schools, community centers, industrial, residential or commercial areas.

Project support – are the local users likely to support the initiatives and become engaged in the project (renters vs. property owners).

Mature vegetation – large trees can be a constraint particularly in municipalities with tree protection bylaws.

Figure 4.3.34: Further consideration of user behavior may have resulted in a different LID solution for this location. This section of sidewalk is a preferred smoking location for the adjacent business and the cigarette butt waste stuck between the permeable pavers will be an ongoing maintenance problem. (Source: CVC)

Underground and overhead utilities – utility conflicts may eliminate an LID option but there are workaround solutions (see Chapter 9).

Accommodation of surface elements – location, sizing, and spacing of LID practices must consider surface elements such as light standard, transit shelters and fire hydrants. The structural support of these also must be considered, for example a light standard near bioretention may require a deeper base.

Current or future transportation requirements - transportation planning initiatives can be integrate into the ROW retrofit design objectives to facilitate future projects.

Existing aesthetic character of the site – neighborhoods with established gardens, mature trees, and professionally landscaped frontages may be more receptive to a higher landscape aesthetic of vegetated LID practices such as bioretention or bioswales.

Existing maintenance protocols and equipment – how is the ROW currently maintained and can the same techniques be used after the LID practice is constructed.

Impacts to local drinking water wells – consider if threats under Source Water Management Plans have been identified.

Encroachment issues (residents encroaching within the ROW) – including fences, driveways, or other structures

Often, problems with the performance of an LID feature can be traced back to oversights in the design. It is critical to give proper consideration to all the factors that affect the location of the practice.

Traffic safety issues – are there reports or records of increased traffic issues. If so consider how the LID practice can be used to address the issues.

Parking availability and access – where parking must be preserved, permeable pavement should be considered, but where parking is underused, then impervious area can be reduced with curb extensions or reduced street width.

Additional benefit opportunities – are there other retrofit opportunities that can be incorporated into the retrofit such as park improvements, trail connections and educational signage potential.

Existing municipal policies and by-laws – The existing policies and by-laws review should not be considered as barriers to the project, but instead should be considered in the context of points of discussion for the municipal project team during the implementation process. Undertaken in the context of a demonstration project, the existing by-laws and standards can be relaxed and reviewed within a controlled environment. With all the departments leads present, a demonstration project can be an opportune time to discuss and re-evaluate. Typical municipal codes, standards and by-laws to be investigated may include:

- Noxious weed by-laws – can exclude native species and limit plant selection. Redefinition and re-evaluation of plants within these lists may be warranted.
- Property standards by-laws – can prevent implementation of LID practices such as permeable pavements (gravel or turf stone driveways), bioretention or bioswales which incorporate temporary surface ponding.

Figure 4.3.35: ROW retrofit opportunity – local parkette and pedestrian crossing improvement. (Source: Aquafor Beech)

- Boulevard planting by-laws – can prevent implementation of LID practices such as bioswales due to plant type and height restrictions of planting along municipal ROW and boulevards.
- Standing water by-laws – can prevent implementation of LID practices which incorporate temporary surface storage. The definition (or redefinition) of 'standing water' to allow for up to 48 hours of ponded water within LID practices may be warranted.

To reduce design and construction costs, O&M and inspection requirements consider using lower maintenance plantings such as perennial grasses or substitute perennials for turf or round stone.

4.4 Costing tools

A significant factor in determining which LID option is most suitable is the capital and lifecycle costs associated with design and construction. Table 4.4.1 provides a high-level costing tool to assist municipalities with LID screening based on this factor. Capital costs for construction projects are often stated as a value per unit of installation. For options where significant costs are linear, such as curbs and pipes, the value is presented as a value per metre of road construction. For options where the cost is more easily scaled based on surface area, the value is stated per square metre. For stormwater retrofits, it is valuable to present capital costs as a value per upstream impervious drainage area.

One tool for comparing the costs for making quick cost comparison of various LID options is the LID Practices Costing Tool developed by the TRCA Sustainable Technologies Evaluation Program (STEP). The spreadsheet tool will calculate capital costs and 50 year lifecycle cost estimates for bioretention (includes bioswales), permeable pavement, infiltration trenches (includes perforated pipe systems), and enhanced grass swales. Users can adjust various assumptions (drainage area, soils, full or partial infiltration, sizing criteria) to cost many scenario quickly. The tool may be downloaded from the STEP website at sustainabletechnologies.ca

Table 4.4.1: High level costing tool for LID option screening[80,81,82,83,84]

LID retrofit option	Cost per impervious drainage area	Construction cost
Bioretention planters	41 – 83 ($/m²)	264 - 484 ($/m²)
Curb extensions	9 ($/m²)	n/a
Boulevard bioretention	40 - 65 ($/m²)	108 ($/m²)
Bioswales	7 - 23 ($/m²)	594 - 2585 ($/m²) / 300 – 400 ($/m)
Perforated pipe	55 ($/m²)	150 - 250 ($/m)
Permeable pavement	53 - 60 ($/m²)	108 - 430 ($/m²)

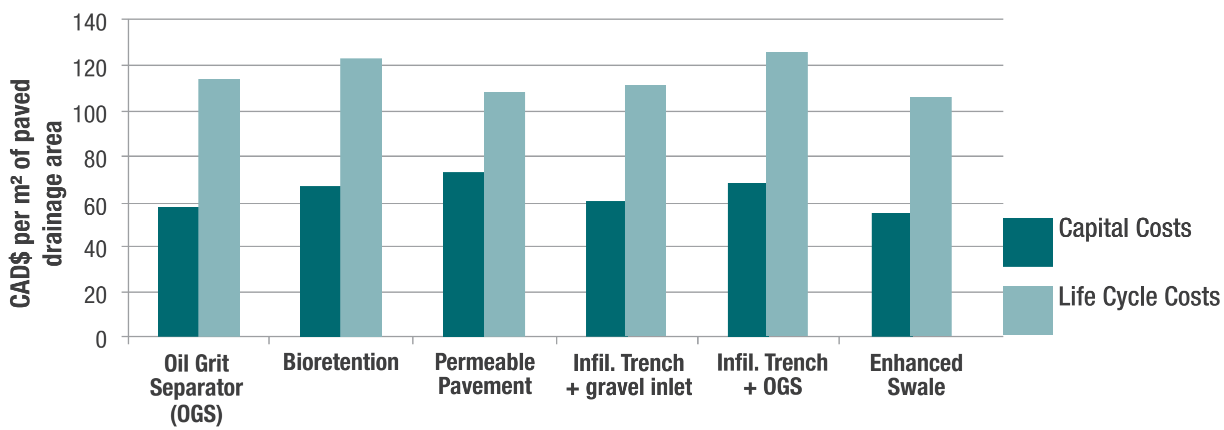

Figure 4.4.1: Comparison of capital and life cycle costs for different asphalt runoff treatment scenarios using the STEP LID Practices Costing Tool [85].

Another method of evaluating LID road retrofit projects is to use a Cost Effectiveness Tool. Cost effectiveness examines both the direct and indirect costs associated with a particular option, and the corresponding direct and indirect benefits. This method is ideal for comparing alternatives with significant differences in the benefits provided by each alternative. By examining both direct and indirect costs/benefits, this approach is used widely for assessing infrastructure investments and used in the development of Asset Management Plans.

An example of a Cost Effectiveness Tool is provided in Table 4.4.1, and instructions and how to use the tool is provided in the following sections. For further assistance on developing Asset Management Plans and the use of a Cost Effectiveness Tool to compare conventional road infrastructure to LID , refer to Appendix B.

Project costs

Staff time, external labour, equipment, and materials are common factors to consider when evaluating the overall cost of a project. A comprehensive analysis of project costs considers all lifecycle stages of a project. Additional costs include capital expenditures for planning, design, and construction. Lifecycle costs should also be considered at this stage. These costs include operations and maintenance, removals and disposal fees. In the Sample Lifecycle Cost Effectiveness Tool these costs are grouped together as "direct project costs".

The second category, "Indirect project costs", may not apply to all LID options. Indirect costs include permitting fees, costs associated with land acquisition, ongoing utility or energy fees, and costs associated with sampling and analysis. If a project option does not include indirect costs, the cell can be left blank.

For each ROW option, the total project cost is the sum of the direct and indirect project costs.

Project benefits

LID practices are added to ROW projects to achieve benefits beyond the scope of conventional road infrastructure. LID practices are most commonly added to ROWs to reduce pollutant loading from stormwater and to reduce the total volume of runoff produced from storm events. In the sample Cost Effectiveness Tool, project benefits have been identified as either direct or indirect. "Direct project benefits" are primary goals, objectives, and targets of the retrofit. Achieving these benefits is often the motivation for installing LID practices within a ROW. Direct benefits may include volume reduction, erosion control, water quality treatment, and flood control. Direct benefits often have quantifiable targets such as infiltration volumes, flow rates, and expected pollutant load reductions. Project options will provide these benefits to varying degrees. In the sample Cost Effectiveness Tool, each option is given a score from zero through three.

LID practices often provide benefits beyond those that are targeted as direct benefits. These "indirect project benefits" can include building climate change resiliency, greening neighbourhoods, reducing urban temperatures, providing a buffer for road noise, and improving street aesthetics. Indirect benefits that are important to your municipality can be found in environmental strategic or sustainability plans.

Weighing project benefits

In the sample Cost Effectiveness Tool, each direct benefit is equally weighted for a total possible direct benefit score of 12 (3 points x 4 possible benefits). Each indirect benefit is also weighted equally with a total possible indirect benefit score of 9 (1 point x 9 possible benefits). In setting up your own cost effectiveness tool, you can apply different point values if specific benefits are high priorities for your municipality.

Cost effectiveness

The final score is determined by dividing the total project cost by the overall benefit score. A lower final score indicates that the option is more cost-effective and offers the best value.

Table 4.4.1: Sample cost effectiveness tool

Cost effectiveness analysis		Option 1	Option2	Option 3 1	Option 4	Option 5
Direct project cost		2				
Indirect project costs			3			
Total cost						
Direct benefits 0=objective not met 1=objective met 2=objective exceeded 3=objective greatly exceeded				4		
Direct benefits total						
Indirect benefit y = provides benefits n = does not provide benefits				5		
Indirect benefits total						
Additional cost (compared to conventional road replacement)				6		
Cost effectiveness (additional cost/sum of direct and indirect benefits) - Lower is more effective					7	
Rank						

- Comments:

1	Project options are listed in these column headings. The first option should be the standard practice (e.g. the conventional road reconstruction). Project options may differ greatly (e.g. conventional stormwater management and LID practices) or may be variations of the same practice (e.g. bioretention and bioretention with phosphorus removal media).
2	Direct project costs are displayed in these cells. Direct project costs include both capital and lifecycle costs that will be required for most project options. This includes planning, design, construction, operations and maintenance, as well as replacement and disposal.
3	Indirect project costs are displayed in these cells. These costs include permitting fees, real estate costs for land acquisition, energy utility costs, and costs associated with sampling and analysis.
4	Direct benefits are goals, objectives, and targets that the project must be designed to achieve. Stormwater criteria should always be direct benefits. Other direct benefits for road retrofits may include neighbourhood aesthetics or parking requirements. In these cells, each option receives a score from 0 (does not meet objective) to 3 (greatly exceeds objective). The scores for each option are added for a total direct benefit score.
5	Indirect benefits are additional benefits that can be achieved beyond primary goal, objectives, and targets. Consult municipal sustainability plans or strategic plans for indirect benefits. In these cells, each project option receives a Y (yes) or N (no) indicating whether each indirect benefit is achieved. The scores for each option (1 for Y, 0 for N) are added for a total direct benefit score.
6	For each project option the additional cost is equal to the total cost minus the total cost of option 1 (the standard practice).
7	To compare cost effectiveness the additional cost should be divided by the total benefit score. The lower this value is, the more cost effective the project option is at providing benefits. Based on these results each option is ranked.

5.0 Pre-Design

Now that you have conducted site reconnaissance and screened options for a preferred alternative, it is time to proceed to the pre-design phase of the project. Pre-design tasks are aimed at further understanding the physical characteristics of the road retrofit site and identifying potential design constraints and opportunities during the detailed design phase. The following section provides the types and sequence of activities that should be undertaken as part of the pre-design process.

5.1 Utility locates

Utility locates are undertaken prior to geotechnical investigations and related drilling activities. The company selected to complete the geotechnical investigation is usually responsible for obtaining utility locates. Utility locates can be scheduled by contacting the Ontario One-Call service.

Locates generally expire in 90 days, so be sure to coordinate infiltration testing soon after geotechnical work is completed.

5.2 Geotechnical investigation

Geotechnical investigations are necessary for most LID practices implemented within the municipal ROW. However, the scope of work will vary depending on the chosen LID practice. Table 5.2.1 provides a summary of the geotechnical investigation activities necessary for the detailed design of the LID measures suitable for municipal ROWs.

Figure 5.2.1: Before undertaking a geotechnical investigation, consider what equipment will be required. Where large equipment such as a drill rigs is required it is essential to ensure there is a safe ingress and egress for all equipment and people. Also consider how the work will affect user of the ROW and adjacent properties. Traffic controls may be required on confined or busy roads. (Source: Aquafor Beech)

Table 5.2.1: Summary of geotechnical investigation activities.

LID practice	Geotechnical investigation activities			
	Boreholes	Piezometers	Laboratory soil testing	Soaked CBR test
Bioretention	●	●	●	
Bioswale	●	●	●	
Perforated pipe	●	●	●	
Enhanced grass swale			●	
Permeable pavement	●	●	●	●
Prefabricat-ed modules	●		●	

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Activities for LID practices implemented within the ROW

Boreholes

Boreholes are typically specified to a minimum depth of 3 m or to bit refusal. It is recommended that boreholes be advanced a minimum of 1.5 m below the proposed invert of proposed LID practices. The resolution of the investigation (i.e. quantity and spacing between boreholes) will vary from site to site. At each borehole drilled, the following should be noted:

- Soil horizon
- Soil texture and colour
- Soil colour patterns
- Depth of water table (if encountered)
- Depth of bedrock (if encountered)
- Observations of pores or roots
- Estimated type and percent of coarse fragments
- Hardpan or other limiting layers
- Strike and dip of soil horizons

Soil samples should be taken at various levels. Analysis of soil samples will provide details on soil characteristics, which in turn will help to better tailor detailed designs to site conditions. A benefit of this approach is that it can lead to cost efficiencies through the use of native soils instead of imported soils if they meet the design requirements of the LID feature.

Piezometers / monitoring wells

Monitoring wells consist of 50 mm diameter piezometers installed to depths of 3.7-4.5 m and encased within an above-ground, lockable, steel housing. Monitoring wells determine the pre- and post-construction seasonal high water table and groundwater flow direction. They can be used when available data from background documentation or previous investigation is not available.

Laboratory soil testing

Soils samples collected as part of geotechnical investigations characterize the soil properties including natural moisture content, plasticity characteristics, particle size distribution, and analytical results for contaminates. It is beneficial if geotechnical investigations include recommendations regarding soil disposal alternatives.

Need more guidance on soil and infiltration testing? Refer to Appendix C of the LID Stormwater Management Planning and Design Guide at bealeader.ca

Soaked California Bearing Ratio (CBR)

Soaked CBR is required only for the design of permeable pavement. Geotechnical investigations must include recommendations for base and sub-base requirements and other measures required to ensure adequate structural strength, such as compaction or geosynthetic requirements.

In-situ infiltration testing

In–situ infiltration testing characterizes the hydraulic properties of the existing native material on-site. On-site infiltration testing using the Guelph Permeameter test to determine the in-situ saturated hydraulic conductivity and the design infiltration rate per the LID Stormwater Planning and Design Guide (Appendix C) is recommended. Testing should be performed within the approximate location and invert of proposed LID practices.

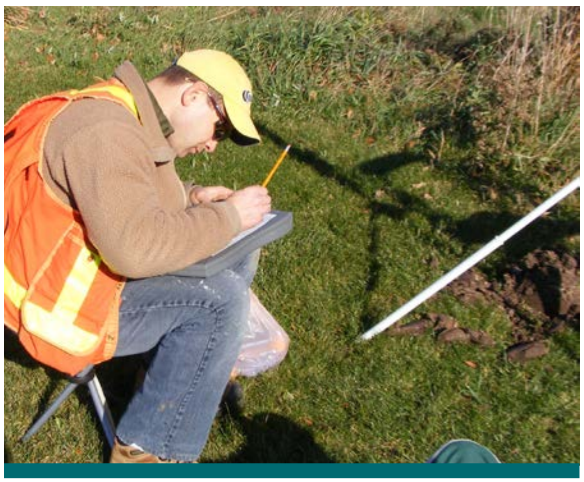


Figure 5.2.2: Fast-moving soils full of gravel and cobble will use a lot of water during testing and augering this material is difficult. Be well equipped with shovels, a sufficient water supply, and other equipment when testing. When soil testing clay materials, bring a comfortable chair. (Source: Aquafor Beech)

Interpreting the data

The results of the geotechnical investigation will identify good and bad spots for installing infiltration practices. The data collected will establish infiltration rates that can be used to pick optimal areas to install the LID practices. The information can help with sizing the practices. The goal of this testing is to ensure that the practice will provide the best performance at the lowest cost.

5.3 Tree inventories

A tree inventory determines the trees that should be preserved and accommodated within the design or deemed eligible for removal. A certified arborist or botanist should conduct the tree inventory assessment. A comprehensive assessment will include the following information:

- Tree health
- Crown reserves
- Diameter at Breast Height (DBH) (minimum of 10 cm DBH for preservation)
- Record GPS coordinates or note approximate tree locations on available mapping.

Most municipalities have tree by-laws and policies which detail assessment, preservation, and compensation criteria. Consult local tree by-laws prior to conducting tree inventories. If no local tree by-laws are available, determine tree inventory criteria with local municipality representatives. In general, consider the following criteria in absence of municipal by-laws:

- Trees with 10 cm or greater DBH are preserved
- Trees removed with a DBH of 10 cm or greater shall be compensated at a rate of 3 to 1.

Figure 5.3.1: A tree inventory will focus on what tree species are present, and their condition. (Source: Aquafor Beech)

5.4 Topographic survey

To produce base mapping for the detailed design phase, it is necessary to do a topographic survey of the site using total station survey or GPS equipment. Surveys should include the following site features:

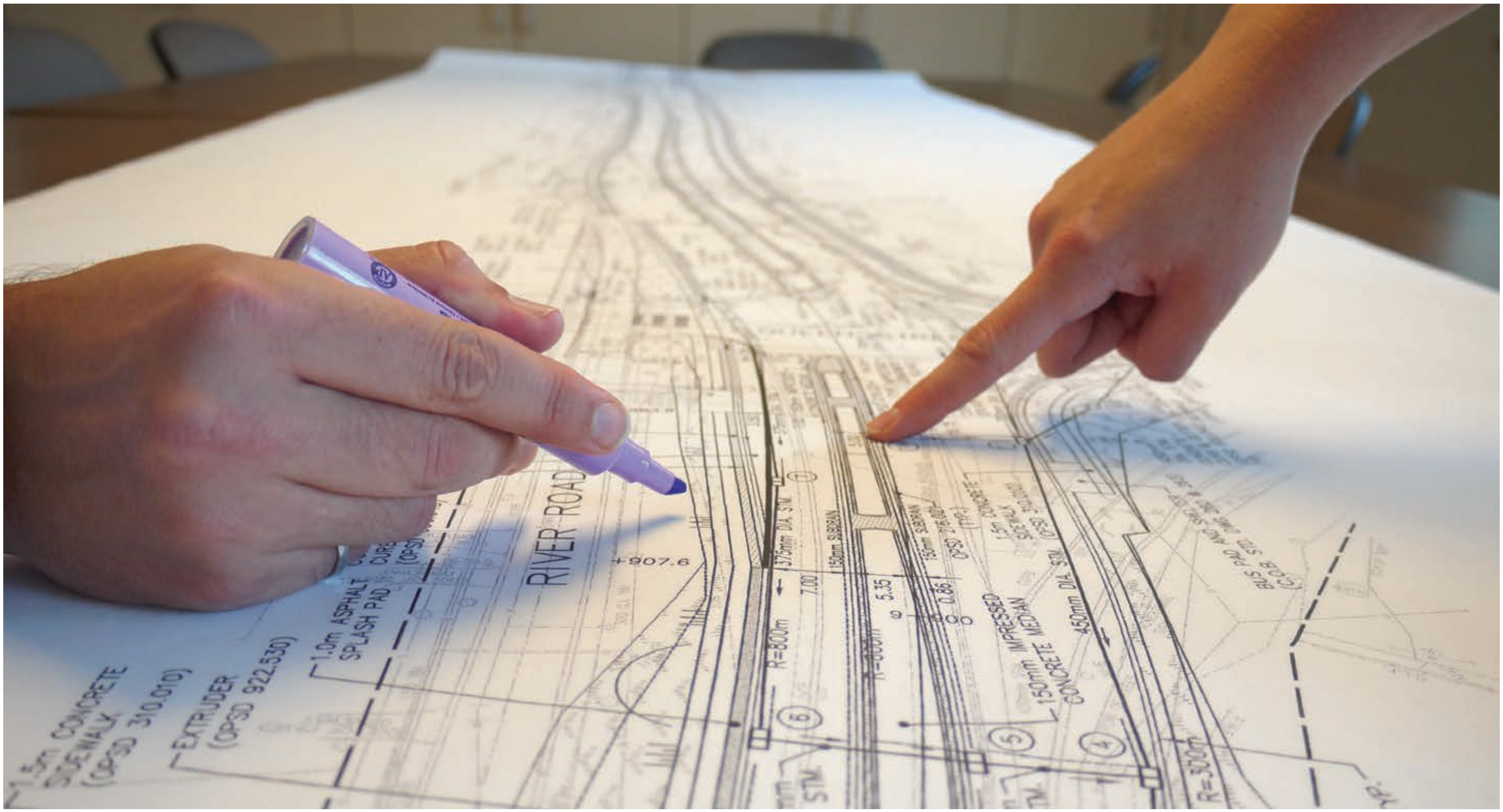
- Topography of the proposed site
- Identification of above ground and below ground services
- Utility locate markings
- Inverts and sizes for existing sewers, catch basins, manholes, etc.
- Location and description of on-site structures
- Available legal monuments
- Borehole locations
- Infiltration testing locations
- Significant vegetation (coordinated with tree inventory assessment)
- Existing parkland features
- Fence lines and existing landscaping
- Local benchmarks

Municipalities generally have GIS or AutoCAD layers of existing utilities, land parcels, and property lines. Add these features to the survey to create base mapping templates for use during the detailed design phase.

You might need to establish local benchmarks to provide horizontal and vertical controls that the contractor will require during construction. Survey temporary nails or markings etched into existing structures, such as curbs or headwalls, to determine local benchmarks.

Figure 5.4.1: It is important that the survey includes all relevant design information. The location of boreholes and infiltration tests should be included. Ensure that appropriate coordination takes place with team members responsible for other pre-design field work. (Source: Aquafor Beech)

6.0 Detailed Design



The detailed design process for LID practices is a multi-step approach. The process utilizes the information obtained during the background review and pre-design processes to guide the development of the detailed design. The ultimate product generally consists of design drawings and briefs which are utilized by the contractor during construction. The multi-step process is as follows:

Step 1: Review design guidelines and requirements
Consider municipal, regional, and agency design guidelines and criteria.

Step 2: Catchment area development
Develop base mapping and delineate drainage areas to proposed LID features.

Step 3: Hydrologic and hydraulic assessments
Quantify site hydrology including runoff volumes using standard hydrologic/hydraulic methods and models.

Step 4: Design optimization
Evaluate other design considerations which may enhance the primary design objective. Creative thinking and simple solutions to design problems often save costs and reduce construction efforts.

Step 5: Design drawing and brief development
Develop detailed design drawings and briefs for use by contractors during construction.

6.1 Review design guidelines and requirements

During the detailed design of LID practices, it's important to review and consider municipal, regional, and agency design guidelines and criteria. Such documents provide design criteria and targets for LID practices with regards to water quality, quantity, and erosion control.

The LID Stormwater Planning and Design Guide provides specifications, sizing criteria, design examples, typical details, and requirements for the majority of LID practices.

6.2 Catchment area development

Development of base mapping using topographic survey and background information provides the foundation for developing detailed design drawings. Base mapping should include:

- Utility, property line, land parcel, watercourse, infrastructure and other layers from municipalities
- Survey points including symbols/descriptions of features
- Locate information
- Borehole and infiltration testing locations
- Structures and utilities
- Contours
- Aerial photos

From base mapping, drainage areas and overland flow patterns can be mapped to determine the existing drainage networks. The pre-construction drainage network is used for hydrologic and hydraulic assessment to determine runoff volumes.

LID designs often break the larger drainage areas of traditional stormwater systems into smaller drainage areas and sometimes require changes to flow paths to get runoff to a LID practice.

Other reference documents include:

- Ontario Ministry of the Environment Stormwater Planning and Design Manual (2003)
- CVC's LID Construction Guide
- CVC's Landscape Design Guide for Low Impact Development
- Local municipal standards for stormwater management and development criteria
- Agency standards for stormwater management (i.e. governing Conservation Authority)

6.3 Hydrologic and hydraulic assessment

As ROW surfaces change from impermeable to pervious and runoff retention practices are added, the quantity of runoff during rainfall events decreases, which in turn reduces the flows and strain on downstream municipal storm sewers. With significant alterations to the hydrologic characteristics of drainage areas, it is recommended that a hydrologic and then hydraulic assessment of proposed LID drainage networks be performed.

The hydrologic assessment factors the physical characteristics of the land surface and rainfall intensities into expected runoff volumes from the land surface. Most municipalities have design standards for drainage and stormwater works which detail Intensity-Duration-Frequency curves for the 1-in-2-year through the 1-in-100 year design storms. Municipalities usually specify the minor system sizing requirements for storm pipes and swales. Using applicable design storms, runoff coefficients, and contributing drainage areas will provide estimations of the runoff flows and volumes expected for relative drainage areas.

During the hydraulic assessment, use the hydrologic assessment results to size underdrains, inlets, and overflows and ensure there is sufficient capacity to convey the runoff peak flow rates produced from the applicable design storms.

Use desktop analysis or a more sophisticated computer-based modelling approach used to model the hydrologic and hydraulic characteristics of a given LID design.

6.4 Street profiles, inlets and outlets

The existing (or planned) profile of the street as well as the type(s) of inlets and overflows that will convey stormwater to and from LID practices must be considered early in the design process. The appropriate design and construction of roads (in particular its profile and grading) as well as the LID inlets and outlets is especially critical as small variations in slope, structure or grade can pose a significant barrier, causing bypass of the LID practice.

Street profile

Alterations to the street profile will affect the volume of water conveyed to the LID practice. Streets can be crowned, reverse crowned, drain to one side, or flat.

Crown: The most common street profile is a crowned street with stormwater draining to the sides of a street. Traditional design often includes a curb-and-gutter system directing flow into a stormwater drain inlet. A variation of the crowned street is a "double-crown street." This type of street has two crowned profiles next to each other with a median in the middle. This profile is common to arterial streets.

Reverse crown: A reverse-crowned street is the opposite of a crowned street and directs runoff to the centre line of the street. This profile is common to alley ways, arterial streets, and even freeways. Typically LID practices are built in the centre median.

Side shed: The side shed involves directing all the water to one side of the street. This road drainage profile is common for roads built into significant slopes. For this profile, LID established on the down gradient side of the ROW can accept runoff from the entire ROW via overland flow.

Flat: Typically, these streets are graded slightly so they drain to the sides or center during major events. Flat drainage is possible with the use of pervious paving techniques. With pervious paving, the primary drainage of water is directly through the paving surface into the subsoil.

Inlets & Outlets

There are a variety of different methods and structures that can be used to convey stormwater into and out of LID practices. These approaches can have a significant impact on the performance of a LID road retrofit – it is important that the right type of inlet/outlet be selected and that particular attention is paid to ensuring that their structure, grade and/or slope is appropriate.

Curbs/curb cuts

The Ministry of Transportation's Ontario Provincial Standards (OPS) provide design details for most standard curbs. As LID design is a newer approach, consider certain amendments to existing standards to ensure runoff enters the LID practices. Runoff is directed into stormwater facilities in two primary ways: sheet flow and curb cuts. Table 6.4.1 demonstrates the benefits and issues of each inlet method and the type of standard curbs for consideration during the design phase.

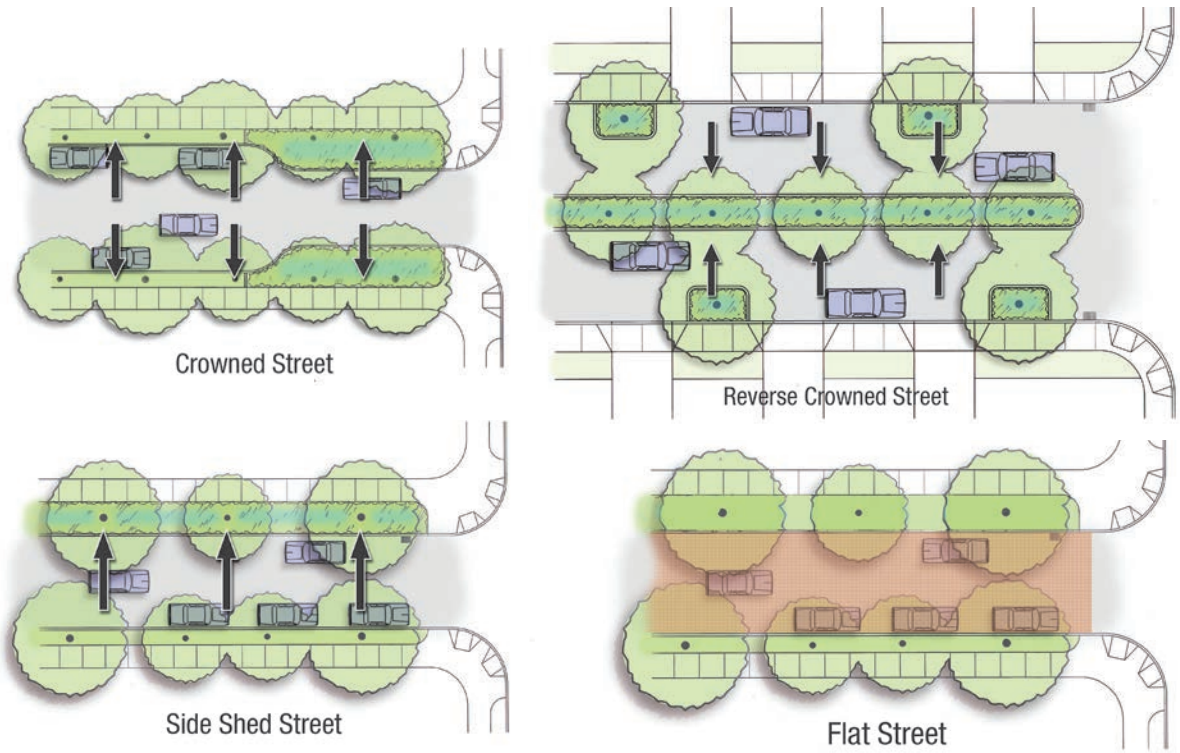


Figure 6.2.1: The existing road surface profile can dictate the positioning of LID practices during a retrofit. (Source: San Mateo County)

Table 6.4.1: Benefits and issues of curb selection.

Flow type	Benefits	Issues	Curb options
Sheet flow	• Even flow distribution • Minimal risk of clogging • No energy dissipation measure required	• No barrier for vehicular traffic	• Concrete band edging • No curb • Sidewalk
Curb cuts	• Barrier for vehicular traffic • Better for streets with higher traffic volumes • Better for slow traffic and pedestrian friendly streets • Prevents parked vehicles from encroaching on boulevard space	• Concentration of flows and volumes • Sediment build-up • Energy dissipation to reduce erosion	• Mountable • Barrier • Semi-mountable
Curb accessories - inlet structures and trench drains	• Allow for a continuous curb line • Could have an easily maintained pre-treatment sump	• Higher cost option • Could require an elevation drop or subject to grading issues • Inlet may require more frequent maintenance	• Mountable • Barrier • Semi-mountable

Sheet flow design considerations

- Concrete flush curbs allow stormwater to flow evenly into LID features
- Energy dissipation methods such as pea gravel or round stone are necessary to reduce erosion

Curb cut design considerations

- Curb cuts should be as wide as possible to accept flow and spaced frequently to distribute the water flow evenly
- Covered or notched curb cuts may require more maintenance as openings area restricted but protect curbs during snow removal operations
- On steeper streets, it is recommended to build a small, low-profile asphalt or concrete berm at each curb cut inlet to guide flow, otherwise runoff may bypass LID features during intense storm events

The following pages illustrate the most common ways that runoff enters LID practices within the municipal ROW and details the problems and key consideration during design process.

Figure 6.4.1: Flush curbs on both sides of this street allow for drainage from left to the bioswale on the right. (Source: City of Vancouver)

Figure 6.4.2: Ensure that grates are corrosion resistant and have anti-slip measures. (Source: Aquafor Beech)

Figure 6.4.4: A covered curb cut can be used to provide the protection of a curb but allow runoff to enter the facility. (Source: Aquafor Beech)

Figure 6.4.6: Notched curb cuts prevent larger debris from accumulating in bioretention planters. A greater number of curb cuts may be required to allow for design flow conveyance. (Source: Aquafor Beech)

Figure 6.4.3: The gates on this bioretention planter in Kitchener, Ontario are designed to close during the winter season to prevent infiltration of chloride from deicing practices. (Source: Aquafor Beech)

Figure 6.4.5: Inlets and outlets can be incorporated into a manhole by controlling the stage-discharge characteristics with an orifice plate or weir. (Source: Aquafor Beech)

Figure 6.4.7: Consider existing trees, parking spaces and other ROW features when selecting inlet type and location. (Source: CVC)

Outlets & Overflows

Overflow within LID features can be managed in several ways. Overflow volumes may simply be allowed to overflow from the LID measure through a downstream curb cut and discharge back into the street where it can eventually be captured by an existing storm drain inlet or downstream LID feature. Conversely, an outlet located within the LID measure may be constructed which directly connects to a proposed underdrain or existing storm sewer. Table 6.4.2 provides the benefits and issues associated with each inlet method and the type of standard curbs that may be considered during the design phase.

Metal or Plastic Overflows?

Use Metal.

Some inlet types are available in different materials—typically metal or plastic. While plastic is ususally the cheaper option, it is not recommended for street-level LID practices. Plastic inlets are easily weathered by sun and moisture, making them brittle and susceptible to damage or vandalism.

Table 6.4.2: Benefits and issues of overflow selection.

Overflow type	Benefits	Issues
Atrium grate	• Less clogging • Self-cleaning as water levels recedes • Improved aesthetics	• More expensive compared to flat grates
Flat grate	• Less expensive compared to atrium grates • Less visible	• Susceptible to clogging
Catch basins	• Anti-vandalism • Robust and resistant to weathering especially if coated • Less visible	• Expensive • Susceptible to clogging
Ditch inlet catch basins	• Anti-vandalism • Robust and resistant to weathering especially if coated. • Self-cleaning	• Expensive • Low aesthetics
Curb cut	• Anti-vandalism • Robust and resistant to weathering especially if coated. • Self-cleaning • Low cost	• Possible only if curb and surface outlet are available

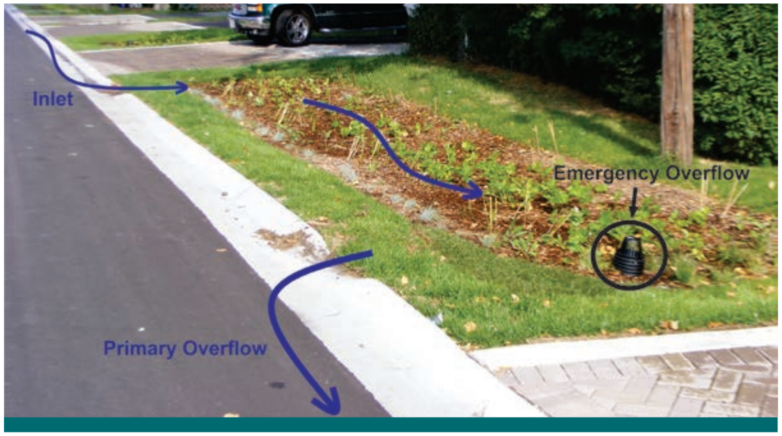


Figure 6.4.8: It is important to maximize the flow path to increase opportunities for filtration and infiltration. The above images of the Lakeview Project show the primary flow path and the location of an emergency overflow. (Source: Aquafor Beech)

Figure 6.4.9: Properly sized grates can prevent debris from accumulating in storm sewers. Steel grates are recommended because they are more durable than plastic. (Source: Aquafor Beech)

Figure 6.4.10: Overflow grate inverts should be surveyed to confirm that they will function as intended during infrequent storm events. Vegetation should be managed around overflow grate inverts to prevent clogging. (Source: Aquafor Beech)

Figure 6.4.11: For bioretention planters with deep, flat-bottomed storage areas, there is more flexibility in placing the overflow spillway because the practice functions as a detention basin, not a conveyance path during infrequent storm events. (Source: CVC)

6.5 Landscape design for ROWs

Landscape design is often an afterthought with many ROW projects. In the case of vegetated LID practices, the vegetation plays an important role not only in the function of the practice, but an equal, if not more important, role in the aesthetics of the practice. It is the vegetated and landscaped components that the public sees, and as such cares most about. As a result, effective landscape design determines the extent to which these LID road designs are accepted.

Rather than being the final design step, landscape professionals need to be involved from the site plan stage and throughout the design process, contributing towards LID decision making, layout, shape and planting plans. The landscape professional plays a key role on the design team in establishing the visual appeal of a LID design and ensuring that the landscaping choices are appropriate to the surrounding land uses. LID landscaping choices need to be tailored to the aesthetic of the surrounding properties and capable of being maintained by whomever the responsible party – municipal public works or adjacent property owners. Formal or informal agreements can be used to ensure long term maintenance, but ultimately the best long term protection for LID practices is an attractive functional design that is perceived as an amenity.

LID landscapes must invoke instant appeal. Design principles for LID practices should conform to typical urban landscaping principles, unlike stormwater ponds or stream restorations which follow natural landscaping approaches. Urban principles include colour, simplicity, mass grouping, rhythmic repetition, balance, consistency of placement and spacing as well as various textures, lines and forms. Favourite urban landscapes have a clean, tidy, orderly appearance.

A more in depth look at LID design principles, considerations, and plant lists can be found in the CVC Landscape Design Guide.

Figure 6.5.1: Bioretenton planters with more elaborate landscaping may be appropriate in showcase areas where the municipality will invest in regular maintenance and beautification. The bioretention planters above are in a downtown high profile location where maintenance regularly occurs. (Source: CVC)

Figure 6.5.2: Boulevard bioretention projects are most successful on streets where residents own their homes and invest in their landscapes, such as in the image above. Note the year round interest, colour, and varied textures in the design above. (Source: CVC)

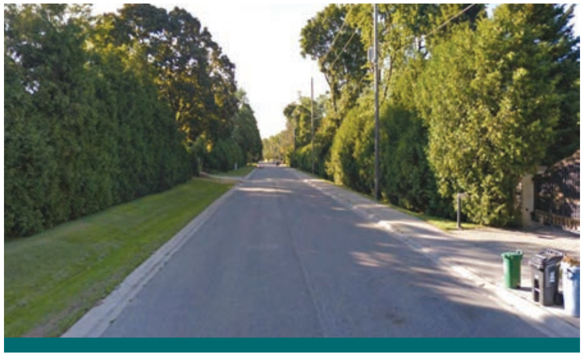


Figure 6.5.3: Low maintenance subsurface practices like perforated pipe systems or enhanced grass swales are best for areas where there is little municipal maintenance and/ or high rental rates. In this picture a grass swale is used above a perforated pipe exfiltration system in Toronto, ON. (Source: CVC)

6.6 Infrastructure and utilities

During any retrofit project, conflicts with utilities and other infrastructure is a possibility. As a general rule, LID design should aim to avoid utilities as much as possible. In a conflict, LID practices can be adjusted to avoid utilities. In cases where area is limited, you may need to consider alternative LID practices.

Management strategies adopted from the San Mateo County Sustainable Green Streets and Parking Lots Guidebook address design issues related to utilities and infrastructure conflicts. Figure 6.6.1 shows management strategies including avoidance, mitigation, and replacement.

Infrastructure and utility conflicts are almost always associated with existing infrastructure and utilities. However, in some cases, proposed infrastructure may cause conflicts during construction that the design phase couldn't foresee. Refer to Section 9.4 for further details on how to handle existing utilities during LID road retrofit projects.

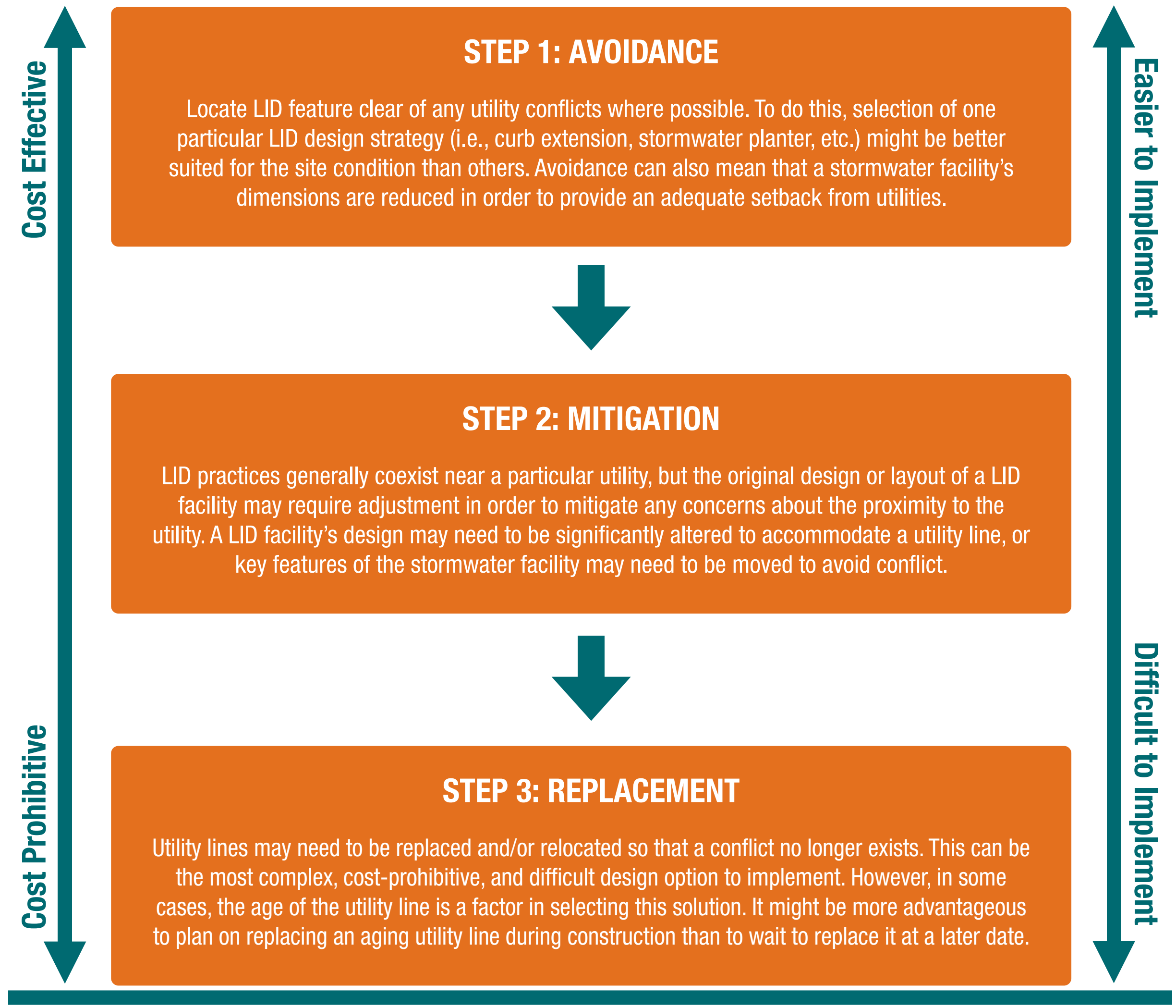


Figure 6.6.1: Management strategies for utility and infrastructure conflicts. (Source: San Mateo County)

6.7 Detailed design drawing standards

This section provides an overview of the detailed design drawing standards to consider when developing design drawings for LID practices.

The typical detail design sheets included as part of a LID design drawing package include, but are not limited to:

- Plan and profiles
- Cross-sections
- Construction details
- Landscape plans
- Phasing plan
- Erosion and sedimentation control plan

Most municipalities, especially larger ones, have design drawing standards and requirements which state the design components to be included as part of design drawings submissions.

6.8 Plan and profiles

The plan and profiles for LID designs within municipal ROWs should detail existing and proposed features as detailed in Table 6.8.1.

Table 6.8.1: Elements of plans and profiles for municipal ROW LID projects.

Plan	Profile
• Road chainage and street names • LID feature locations and numbering • Land parcels and address numbers • Encroachments, trees, other features • Cross-section location identifiers • Manholes, catch basins, other structures • Utilities (invert, obverts, slopes, type and size) • Removal items • Limit of construction • Scale	• Tie-in elevations • Pipe profile including slopes, type, size, inverts, grade changes • Road profile (existing and proposed) • Cross-section location identifiers • Manholes, catch basins, other structures including size and type (sanitary, storm, etc. - indicate pipe direction, inverts and size) • Utilities (invert, obverts, slopes, type and size) • Limit of construction • Scale (x and y axis)

6.9 Cross-sections

At locations identified on the plan and profiles respective cross-sections can be produced to provide a scaled conceptual of the road and LID features located at specific locations. Cross-section details include:

- Road width, expansion areas, and centre line
- LID features including their components and respective dimensions
- Notes and details
- Tie-in locations
- Property lines/construction limits
- Cross section number and chainage/station number
- Scale
- Utilities (type, size, and invert elevation)

Cross-sections are a useful tool to illustrate how LID practices are integrated within the more conventional aspects of a given road.

LID has been incorporated into many types of provincial, regional and municipal roads, from local residential roads to arterials and high density commercial roads. For examples of LID road retrofit projects, refer to Appendix C.

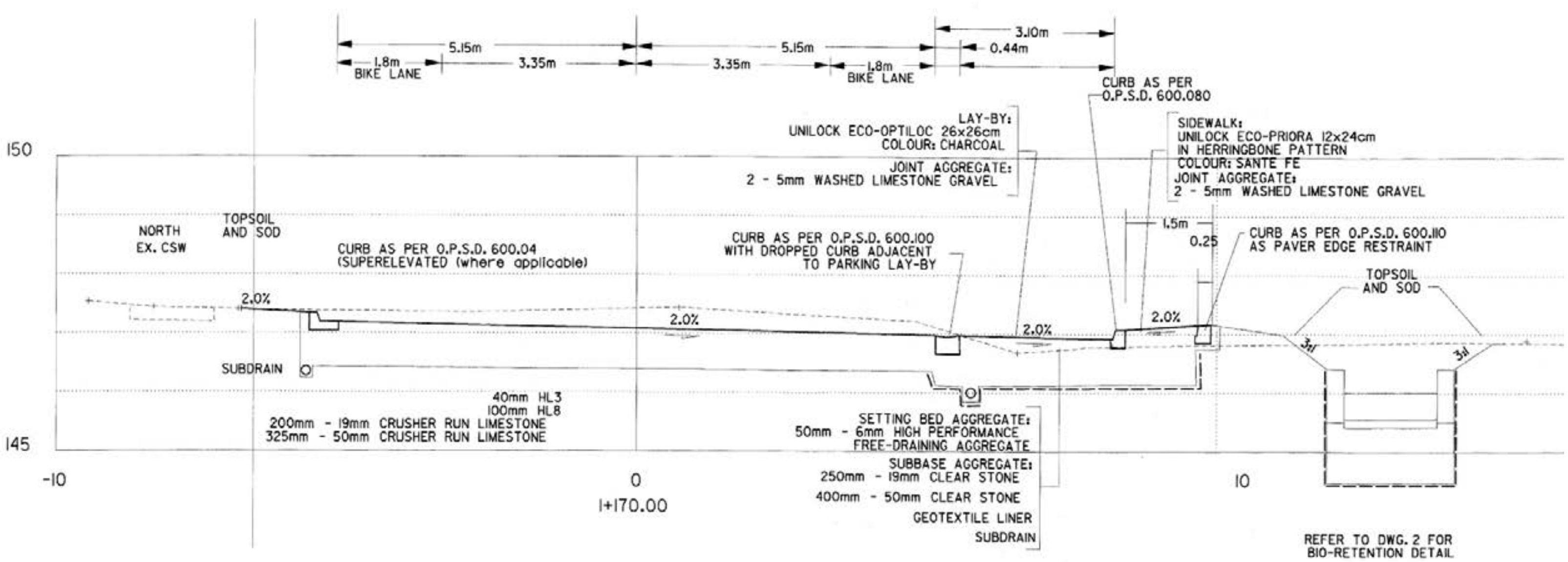


Figure 6.9.1: Road cross-section showing side-shed style road drainage and bioretention planter. (Source: City of Mississauga; The Municipal Infrastructure Group)

6.10 Construction details

Construction detail drawings usually include important details and specifications for required project design elements. This section provides information and examples of the types of design details that might be included as part of design drawings for LID projects within municipal ROWs.

Appendix G contains information and diagrams on design details for various kinds of LID practices.

6.11 Construction sequencing and phasing plans

A phasing plan is a recommended construction plan for the entire design that details the installation sequence of the individual design elements and overall site logistics to consider during construction. Installation/construction sequencing notes are step-by-step procedures that contractors follow when installing LID practices. The Table 6.11.1, which is specific to permeable pavers and bioswale installations, provides a few examples of the various notes included as part of a typical phasing plan.

Table 6.11.1: Typical phasing plan for permeable pavers and bioswale design.

Phase	Note examples
Phase 1 - Site preparation	• Delineate construction limits to be inspected by the engineer before construction works begin • Remove all removal items including curbs, asphalt, and trees • Apply sediment control and/or temporary construction fencing along work area as defined on the erosion and sedimentation control sheet
Phase 2 – Construction of permeable pavers	• Excavate and grade permeable paver area to proposed grades • Install geogrid and filter fabric • Install Granular 'O' and clear stone subbase • Install all proposed subsurface infrastructure including underdrains • Install curb underdrains • Install curbs • Install No. 8 bedding material and permeable pavers
Phase 3 – Construction of bioswale	• Excavate and grade proposed asphalt and bioswale areas • Install all proposed subsurface infrastructure within the proposed base material and bioswale areas, including underdrains • Install filter cloth • Backfill bioswale trench with clear stone • Install bioretention soil media as approved by the engineer

6.12 Landscape plans

Landscape plans and plant selections are important elements of LID practice. In the public eye, the landscaping elements can be a LID project's highest value proposition. Typically, a landscape architect or designer produces the plans.

Landscape plans detail the design's landscaping features and can include planting procedures, installation details, maintenance requirements, and restoration activities. The landscaping plan also details the plant types, densities, planting locations, and quantities required for the design.

Numerous resources for developing landscaping plans are available such as the CVC Low Impact Development Stormwater Management Planning and Design Guide. Other resources included:

- Ontario Ministry of the Environment Stormwater Planning and Design Manual
- CVC's LID Landscape Design Guide
- Local municipal requirements for landscape plan

6.13 Design briefs

Design briefs are documents that accompany detail design drawings and provide a detailed explanation of the design and its function. Design briefs include:

- A summary of background review and site reconnaissance findings, including dates of fieldwork, methodologies, and the existing conditions of the site
- A summary of the results of pre-design activities in addition to dates when in-situ and laboratory testing were performed and methodologies used
- A summary of existing and future drainage areas and corresponding hydrologic and hydraulic assessments
- A summary of design calculations, criteria, reference material, assumptions, and methodologies used to design each LID feature. This should include how pre-design activities influenced the design.
- A summary of the resulting design of each LID feature, including component details such as materials types and dimensions
- A discussion of approval requirements
- Operation and maintenance requirements for each LID practice

6.14 Designing LID for performance monitoring

Performance monitoring allows you to ensure that the LID practice performs as intended. A monitoring plan should be created during the design of the LID features so infrastructure (weirs, manholes, pipes, etc.) can be created to house the monitoring equipment. Planning for monitoring infrastructure and equipment in the detailed design helps to ensure a successful monitoring program. Even if certain features and parameters are not included in the original monitoring plan, it may be beneficial to plan for and create the infrastructure necessary if monitoring may take place in the future. Doing so will eliminate the need for post-construction modifications that could be costly and compromise existing features.

Figure 6.14.1: At the Elm Drive project, the design included a manhole for the collection of water quantity and quality samples, located downstream of the LID practices. (Source: CVC)

Installation of monitoring equipment should not detract from the overall appearance of the site. It is best located out of the publics view. If possible, underground infrastructure such as manholes should be used to house monitoring equipment. Alternatively, secured boxes in lower traffic areas can be used. Properly housed monitoring equipment will help ensure that equipment functions optimally. This is important for getting accurate and reliable measurements.

7.0 Approvals

Like many road projects, road reconstruction or resurfacing with LID requires different approvals at the municipal, watershed, provincial, and/or federal level. As LID adoption is still slow in Ontario, you may encounter policies or by-laws that present a barrier to the implementation of LID retrofits. There are also policies and by-laws that may be enforced by the municipality to facilitate the implementation of LID projects. Staff may not be familiar with LID; this can sometimes lead to resistance or delays in the processing approvals.

In order to ensure timely approvals of LID retrofits, develop a strong understanding of the legislation, policies and by-laws that apply to your retrofit project. This chapter will provide an overview of the typical municipal policies and by-laws, conservation authority requirements, and provincial legislation that can apply to road retrofits incorporating LID.

Approval requirements often differ between different watersheds and jurisdictions. For this reason, a pre-consultation with the appropriate parties is strongly recommended to avoid discovering that the completed design does not conform to the applicable legislation, policies and/or by-laws and has to be redesigned.

Pre-consulting with the appropriate federal, provincial, municipal and agency representatives ahead of time ensures that there is support for a proposed design.

7.1 Municipal policies and by-laws

It is important to conduct a review of policies and by-laws that can affect your project. To identify policies and by-laws that can provide a barrier to the integration of LID practices into municipal ROWs it is recommended that as part of this review you speak and/or request meetings with municipal staff from various departments and other agencies. Possible municipal department representation could include:

- Engineering
- Transportation
- Parks
- Environmental services
- Capital works

Additional consultation may be required with respect to fire safety and access, operations and maintenance requirements and public entity requirements (such as school boards).

To assist with the policy and by-law review process this section identifies some of the typical municipal by-laws that apply to LID roads projects. These are presented in Table 7.1.1.

When by-law enforcement is overly prescriptive or punitive and you predict extreme situations that will affect your project, seek a conflict resolution strategy with municipal staff. Municipal staff can be the best resource when planning your project. Speaking with them can provide an overview of the barrier to integrating LID into road retrofits.

If policies and by-laws create conflicts for LID implementation, amendments can be made or special policy areas created. Demonstration projects are ideal candidates for testing implementation strategies without the need for municipality-wide by-law amendments. Once the necessary changes to existing by-laws have been identified and verified through LID demonstration projects by-laws should be amended to facilitate wide-scale adoption.

Table 7.1.1: Common municipal by-laws affecting LID within a ROW

By-law	General Components of By-law	Barriers/Issues Affecting LID Implementation	Techniques for Overcoming Barriers/Issues
Nuisance weeds and/ or tall grass	• Lists nuisance weeds • Defines a height above which grasses are considered nuisance • Requires cutting tall grasses • Requires a property owner to remove all nuisance weeds • Gives municipality the right to bring properties into compliance at cost of owner	LID practices like bioretention systems can utilize a variety of landscape types, some of which can use a natural landscape approach that may be in violation of height restrictions or nuisance weeds lists.	Work with regulatory officials to permit the construction of demonstration projects that may violate the by-law. Take regulatory officials on tours of LID practices to show how the plantings do not violate the intent of the by-law, and that they provide a pleasing aesthetic in the community.
Property standards	• Requires low lying areas to be filled or graded to a storm sewer • Requires all landscaped areas to be cut and maintained	LID practices like bioretention systems use shallow surface ponding areas that may not be graded to storm sewers and may be left to naturalize.	Emphasize to regulatory officials that ponding in LID practices is limited to 24 hours, and that plantings are intended to be aesthetically pleasing.
Encroachment	• Identifies that personal property including vegetation cannot be located on or extend into municipal property • Allow for encroachment agreements • Gives municipality the right to remove encroachment feature at cost of owner	There may be cases where landowners have encroached onto the municipally owned ROW. To permit construction of LID practices within the ROW these encroachments must be removed.	Enforcing the by-law might be required to integrate conveyance controls into the municipal ROW where fences, hedges, gates, walkways, driveways, and other structures have encroached.
Fence	• Restricts the erection of private fences on municipal property including ROWs • Allows for written authorization from municipality • Gives municipality the right to remove fences in violation	Landowners may have encroached onto the ROW through the construction of fences that extend into municipally-owned land.	Enforcing the by-law might be required to integrate conveyance controls into the municipal ROW where fences have been erected.
Parking	• Restricts parking on municipal boulevards	Landowners or local businesses may have concerns regarding impeding parking or loss of parking spaces. Street parking may have also increased beyond that initially permitted by the municipality.	Enforcing the by-law might be required to allow for integration of curb bump outs, boulevard bioretention systems or other LID practices within the ROW.
Trees	• Outlines tree protection measures that must be adhered to during construction • Identifies specific tree species and sizes that must be preserved	For work within the boulevard, removal or damage to mature trees may be restricted and tree protection procedures will have to be implemented during construction.	Follow the terms of the by-law with respect to excavation and the use of heavy machinery around certain trees species and sizes.

7.2 Provincial legislation and regulation

Ontario Water Resources Act

The Ontario Water Resources Act (OWRA) regulates sewage disposal and "sewage works" and prohibits the discharge of polluting materials that may impair water quality. The OWRA requires that all sewage discharges (including stormwater) be approved by means of an Environmental Compliance Approval (ECA), unless exempted by the OWRA or another regulation. ECAs are issued by the Environmental Approvals Branch of the Ministry of the Environment.

Not sure whether you need an ECA or not?

Schedule a pre-consultation meeting with the Ministry of the Environment and other appropriate parties to clarify whether your site requires an ECA or is exempt under the Water Resources Act.

It is important that site zoning per the Municipal Official Plan be confirmed as the exemption is related to the Official Plan designation and not the type of business being undertaken on the site. Do not assume you are exempt.

If your site already has an Environmental Compliance Approval (formerly known as Certificate of Approval) an amendment is likely required for any alterations and or upgrades to the existing conditions of your approval.

The Ministry of the Environment Environmental Approvals Branch provides ECA pre-consultation for all projects to clarify exemptions and or approval requirements.

Questions related to ECAs should be directed to the Environmental Approvals Branch:

2 St. Clair Avenue West, Floor 12A
Toronto ON M4V 1L5
Phone: 416-314-8001
Toll free: 1-800-461-6290
Fax: 416-314-8452
E-mail: EAASIBgen@ontario.ca

Ontario Stormwater Management Planning and Design Manual

The Ontario Ministry of the Environment's 2003 *Stormwater Management Planning and Design Manual* is used as a baseline reference document in the design of stormwater management facilities, and in the review of stormwatr mangement applications for approval under section 53 of the OWRA.

A common concern among practitioners is using LID to provide enhanced water quality protection in low-permeability (clay) soils. This concern stems from some practitioners' interpretation of guidance provided in the *Stormwater Management Planning and Design Manual*, specifically whether LID can meet Enhanced protection water quality objectives and whether lot-level infiltration on clay soils is permitted.

In the *Stormwater Management Planning and Design Manual*, Enhanced protection is defined as the long-term average removal of 80% of suspended solids. In Table 3.2 Water Quality Storage Requirements based on Receiving Waters of the manual, it is noted that "SMW [stormwater management practice] type that that can be demonstrated to the approval agencies to meet the required long-term suspended solids removal for the selected protection levels under the conditions of the site is acceptable for water quality objectives." As Table 3.2 of the Manual lists infiltration (one of the primary mechanisms of LID practices) as one of the options available to meeting the Enhanced protection requirements, this indicates that LID is a viable option for meeting the criteria.

With respect to clay based soils (predominant throughout much of Ontario) the *Stormwater Management Planning and Design Manual* Section 4.2 and Table 4.1 provides guidance that relates to "physical constraints which could limit the use of lot level, conveyance and end-of-pipe controls." Although the guide provides caution on the use of infiltration practices on clay soils, it does not in any way indicate that soils with lower relative infiltration rates be excluded from infiltration practices.

The infiltration rate of soils will have an obvious effect on the drawdown time of the facility between events, as well as have an effect on the system's performance during an event if the rate of runoff entering the system exceeds the infiltration event. Therefore, should be sized accordingly based on design guidance from sources such as the Low Impact Development Stormwater Management Planning and Design Guide or others. As such, soil infiltration capacity guidance in the *Stormwater Management Planning and Design Manual* should not be interpreted as a prohibition but as a caution that controls relying primarily on infiltration may not be as effective as they could be on soils with higher relative rate of infiltration.

Provided that the proposed LID techniques incorporate the appropriate runoff storage volumes, empty within inter-event periods and are otherwise appropriately sited, designed, monitored and maintained (similar to all other stormwater management facilities), there should be no impediment to the application of LID infiltrating practices to meeting water quality objectives in the *Stormwater Management Planning and Design Manual*. As such, the manual does not prohibit the use of LID practices to meet stormwater requirements.

Ontario Conservations Authorities Act

If the road retrofit project is taking place within a regulated area, approvals from the local conservation authority are likely required. Projects that also fall under the Ontario Environmental Assessment Act should be brought to the attention of the local conservation authority for comment and/or approval.

Conservation Authorities can help

Many conservation authorities have expert staff that can provide advice and guidance on implementing LID projects. Be sure to contact your local conservation authority to learn what approvals are required, if any, and if they can provide guidance, comment on the design or provide other assistance.

Ontario Environmental Assessment Act

The Ontario Environmental Assessment Act sets out a planning and decision-making process to ensure the environmental effects of a project are evaluated and documented prior to decisions being made proceeding to construction. The act applies to most public sector projects unless exempt. Road ROW projects generally fall under the Municipal Class Environmental Assessment process.

Most municipalities generally undertake two forms of roads related projects. These are road reconstruction and road resurfacing. Road reconstruction is most commonly done to convert a rural-cross-section to an urban cross-section. Resurfacing is required for both urban and rural cross-sections at intervals determined by pavement wear. The vast majorities of municipal roads have an existing urban cross-section; therefore the majority of the road projects undertaken within a given municipality are likely to be a resurfacing project of an existing urban cross-section road. Such projects can generally be classified under General Operation and Maintenance of Linear Paved Facilities and Related Facilities of Appendix 1 of the MEA document and will generally be considered as Schedule A or A+ and are pre-approved projects. All resurfacing projects, both urban and rural cross-sections, are considered as Schedule A or A+ projects (Appendix 1, (5a-c)).

The smaller fraction of projects which are road reconstructions can generally be classified under Construction or Reconstruction of Linear Paved Facilities and Related Facilities (Appendix 1 of the MEA document). Such road projects can be relatively large in terms of their total costs, and are subject to the predetermined cost ranges of the Tables of Appendix 1 which determine whether the projects are A, A+, B or C.

The specific Class EA Schedule of individual ROW projects must be determined in relation to the specifics of the road reconstruction project using Part B of the Municipal Engineers Association Class Environmental Assessment document (MEA 2000, as amended 2007), in conjunction with the project schedules in Appendix I.

Ontario Clean Water Act

Ontario's Clean Water Act requires Source Protection Plans, which are locally-driven, watershed based strategies that have been developed through intensive scientific study of drinking water sources in communities across Ontario. Source Protection Plans address activities and land uses around municipal wells and surface water intakes to protect existing and future sources of drinking water. The requirements outlined in these plans are specific to the drinking water source. The goals of LID stormwater management practices are aligned with those of Source Water Protection. These plans should be consulted to determine if specific requirements pertain to your site. Contact your local conservation authority for more information on Source Water Protection.

8.0 Tender and Contract Documents

This chapter provides suggestions for developing special provisions for LID techniques. Use discretion when interpreting and applying these suggestions.

In many cases, when municipalities proceed to the construction phase of planned capital works and other infrastructure related projects, goods and services are acquired from external sources. Municipal purchases must be completed in accordance with applicable provincial and federal laws. These laws state that goods and services must be acquired on a public and competitive basis, unless otherwise stipulated by municipal public policy or by-laws. For example, municipalities often have by-laws which provide exceptions in the event of an emergency constituting imminent danger to life or property (e.g. broken water main). In such cases, pre-qualified sources are generally utilized to provide immediate action. The competitive process often requires the release of a public advertisement requesting the submission of sealed tenders from interested bidders. Tenders are a written formal offer submitted in response to the invitation, in a specific form, to supply stipulated goods or services at a particular price.

The construction and implementation of LID measures within the municipal right-of-way are often associated with road reconstruction, reduction or resurfacing projects. These projects are considered part of roads and public works departments. Tender documents generally incorporate points from the Ministry of Transportation's Ontario Provincial Standards (OPSS) for Roads and Public Works in addition to any municipal amendments (i.e. by-laws). Although the comprehensiveness of tender documents, including its form, may vary from municipality to municipality, the use of OPSS standards make them transferable from one tender to the next.

The following sections provide an overview of the common elements of tender documents including:

- Tender documentation and front matter
- Standard specifications
- Materials
- Testing
- Maintenance
- Construction supervision requirements
- Level of input required by municipal representatives, design consultants, manufactures, and suppliers

The terms "tenderer" and "bidder" are used interchangeably throughout the following sections to refer to the contractor(s) bidding on the tender. Correspondingly, "owner" refers to any municipal body such as a city, town, or village.

8.1 Tender document elements

The information included in tender documents released on behalf of your road ROW project depends on many factors. The size and type of project, accessibility to resources, internal policies, by-laws, and availability of funds all impact the comprehensiveness of tenders and the degree of external resources utilized to assist with their development.

- Tender information
- Form of tender
- Form of agreement
- General conditions
- Special provision and specifications
- Contract documents

Refer to Appendix H for more information on the following components of tender documents.

8.2 Special provisions and technical specifications

Special provisions are technical specifications of products, procedures, and techniques that you include to be followed during construction. Construction supervisors utilize these technical specifications to ensure contractor compliance with the minimum standards.

When you are developing a tender, don't forget about the problem or needs that the design addresses. Make appropriate adjustments to reflect the unique characteristics of the design and overall design objectives.

Special provisions numbers within the tender generally correspond with the Spec # detailed within the Schedule of Items. This structure links the items and associated quantities detailed within the Schedule of Items with the work details provided in the Special Provisions section.

General

All special provisions have common elements. Each special provision outlines the work and items to be included as part of installation; installation procedures; applicable standards and specifications; material and product information; testing requirements; payment structure and decommissioning; and maintenance requirements before, during and after construction. The following is a step-by- step process providing guidance to special provision development for LID practices typically implemented within road ROWs:

Step 1: Clearly outline the work required for each special provision item and list the activities involved.

The work expectation should be clearly detailed as part of the special provision item. For example:
"The contractor shall supply all equipment, labour, and material necessary to construct the bioretention planters as per the design grades as shown on contractor drawings."

- Surface bioswale inlets within the street (curb-cuts) consisting of curbing and apron
- Perforated pipe to outlet: connection of perforated pipe to a permanent positive outlet (if required)
- Supply and install non-perforated pipe sections underneath road crossings (if required)
- Install manufacturer approved connectors for all piping.
- Placement of bioswale aggregate (if required)
- Placement of bioretention soil media

Step 2: Detail the products and material and whether approved equivalents are permissible.

Include any manufacturer and supplier product specifications, installation procedures, maintenance, testing protocols or other details in th tender documents. Prior to issuing approval, the field engineer should review any equivalents the contractor requests. Also include all relevant OPSS and other applicable standards.

Technical specifications of products and materials are dynamic and constantly updated. Technical specifications may also vary by supplier, even when the products seem to be the same. It is your responsibility to prescribe the correct and most recent specifications. For new or special technologies, specifications should include the supplier's name and contact information so contractors can easily find and obtain products.

Specifications for bioretention and bioswales

The following sections provide examples of the various design components of bioretention and bioswale construction as well as product information. Site specific regulations, policies, laws, and any amendments should be considered in this section and clearly stated to ensure enforcement.

Bioswale infiltration trench stone

20 mm double-washed clear stone is often used as the embedding material when an underdrain or subsurface storage is required. 20 mm clear stone is a standard description recognized by most quarries. It is also recognized as ASTM C33 No. 57 stone.

- Double-washed clear stone is typically recommended to reduce the percentage of fines within the bioswale unit. Single washed clear stone may be requested as additional processing generally influences costs.

Pipe and fittings

Selected piping should be rated to satisfy the requirements of the design and application. The applicable pipe specification shall be listed. Information related to the pipe types, sizes, material types, and intended purpose within the design should be listed.

For example:

- Perforated pipe
    - Perforated 300-375 mm dia. HDPE smooth walled collection pipe within bioswale trench
- Non-perforated pipe
    - 300-375 mm dia. HDPE smooth walled collection pipe 3.0m from connection with structures
    - 150 mm dia. HDPE overflow riser extending form collection pipe to bioswale surface invert

Soil media

Engineered soil media is an essential component of bioswales, providing water quality control; however, a fine balance between hydraulic function and retention must be achieved for it to be effective. Table 8.2.1 demonstrates the media specifications stated in the Low Impact Development Stormwater Management Planning and Design Guide for a successful bioswale or bioretention design.

Table 8.2.1: CVC bioretention soil media specifications.

Media	Size	% By Weight
Sand	2.0-0.05 mm	85-88%
Fines	< 0.05 mm	8-12%
Organic Matter	-	3-5%

Additional:

- Cation Exchange Capacity greater than 10 meq/100 g
- pH = 5.5 – 7.5
- Hydraulic Conductivity (K_{sat}) greater than 25 mm/hr

Soil Texture Classification:v

- No objects greater than 50 mm

Specifications for infiltration chambers, soakaways and perforated pipe systems

The components of infiltration chambers, soakaways, and perforated pipe systems are similar to bioretention systems as they include underdrains and open void aggregates as part of their construction. The primary difference between the two is that only bioswales and bioretetion also require bioretention soil media. For details see the Specifications for Bioretention/ Bioswale section.

NOTE: A separate special provision for the type of underdrains and aggregate material may be necessary. Each provision should identify the product specifications and related standards for construction.

Specifications for permeable pavement

Block pavers

All permeable block pavers will have product specifications available from the manufacture or supplier. Information supplied will include physical properties, standard specifications, bedding and base requirements, edge restraints, underdrain requirements and recommendations regarding delivery, storage and handling. All of this manufacturer supplied information should be included in tender documents.

Guidance to permeable block paver specifications are available from the Interlocking Concrete Pavement Institute at icpi.org

Pervious concrete

The effectiveness of pervious concrete as stormwater technology is dependent on product-specific installation requirements. Be sure all information from the concrete manufacturer is provided in the tender package. Information should include:

- Transportation and staging
- Preparation of subbase before application
- Details on moisture content requirements and how to augment if necessary
- Forming requirements
- Compaction and vibration requirements
- Application timing restrictions
- Screening requirements
- Tamping requirements
- Jointing requirements
- Instruction for contact structures such as manholes and catch basins
- Covering after application (specify for different weather scenarios)

Porous Asphalt

Due to the reduced fines content, the application of porous asphalt varies significantly from conventional asphalt. It is essential that manufacturer specified instillation procedures are followed. All information provided by the asphalt manufacturer must be provided in the tender package including:

- Transportation and staging
- Preparation of subbase before application
- Required temperature ranges for installation
- Lift depths
- Screening requirements
- Edging instructions
- Instruction for contact structures such as manholes and catch basins
- Rolling instructions
- Timing instructions
- Layering requirements
- Finishing requirements

In addition, the grading requirements of any base material and bedding material, geotextiles, geogrids, liners, or other base related requirements (e.g. Granular "O" and bedding requirements) for permeable pavements may be specified under the special provision.

Table 8.2.2: Grading requirements.

Granular base grading requirements		Bedding and void opening agregate grading requirements	
OPSS 1010 Granular "O"		ASTM C 33 No 8	
Sieve Size	Percent Passing	Sieve Size	Percent Passing
1 ½ in (37.5 mm)	100	½ in (12.5 mm)	100
1 in (26.5 mm)	95 to 100	3/8 in (9.5 mm)	85 to 100
¾ in (19.0 mm)	80 to 95	No. 4 (4.75 mm)	10 to 30
½ in (13.2 mm)	60 to 80	No. 8 (2.36 mm)	0 to 10
3/8 in (9.5 mm)	50 to 70	No. 16 (1.18 mm)	0 to 5
No. 4 (4.75 mm)	20 to 45		
1.18mm	0 to 15		
75μm	0 to 5		

Step 3: Outline the execution procedures for installation.

As LID practices may be new to members of the construction team, construction guidance and installation procedures should be provided. Execution procedures should provide a clear overview of the installation and emphasize critical elements. Incomplete or poorly communicated details may cause confusion. All relevant OPSS and other applicable standards should be included where applicable.

Execution for bioretention and bioswale installation

This list provides typical execution procedures associated with bioswale and bioretention construction. When compiling execution details, consider site-specific details:

1. Follow contract drawings and details for the layout of gravel trenches and sub-drain.
2. Execute excavating trench and backfilling in accordance with design drawings and notes. Do not place bedding or sub-base material prior to approval of trench excavation by field engineer.
3. Line trench with filter fabric, backfill trench with clear gravel and consolidate in lifts as specified in details.
4. Line top of gravel trench with filter cloth providing separation between soil media and aggregate.
5. Ensure pipe interior and coupling surfaces are clean before laying. Do not use any type of shim to establish pipe slope.

6. Construct trenches to assure a uniform slope ensuring trench bottoms have clean, firm and uniform grade, sloped as indicated on plan.
7. Keep the subgrade elevations parallel with finished elevations.
8. Properly slope perforated sub-drains and lead them to a permanent positive outlet in accordance with connection details.
9. Place standpipes and overflow risers as shown in the details. Prior to placement of this pipe, the subsoil drainage system for the bioswales must be complete and functioning.
10. Connect standpipe riser at bottom of system. Use standard manufactured approved pipe couplings. Cut pipe accurately and work into place without springing or forcing. Ream pipe ends and free pipe and fittings from burrs.
11. Extend the standpipes and overflow risers should extend above finished level as specified.

Specify installation procedures for plant material including trees, perennials, sod, and seeding. Obtain these installation requirements from the landscape designer or architect responsible for the landscaping plan (if included).

Execution for infiltration chambers, soakaways, and perforated pipe systems installations

Similar to the specifications section, the execution procedures for infiltration chambers, soakaway pits, and perforated pipe systems are similar to bioswales as they include underdrains and open void aggregates as part of their construction. Again, the primary difference between the two is the aforementioned systems do not include bioretention soil media. For execution details see Execution for Bioretention/Bioswale Installation section.

Execution for permeable pavement installations

Most permeable pavement products have installation procedures available from the manufacturer or supplier and should be integrated into the special provision section. Information may include procedures and required equipment for installation of the pavement structure, bedding and base, edge restraints, and underdrain. Block patterns for pavers should be part of the tender drawings.

Step 4: State any testing requirements

Any testing of material or products required by the engineer or owner should be clearly stated in the tender.

Bioretention and bioswale media testing

Filter media is an essential component of bioretention and bioswale design as it is responsible for the filtration and percolation of stormwater runoff and overall water quality benefits. Filter media that does not meet specifications can cause bioretention practices to fail. Testing filter media prior to installation is highly recommended. This list provides detailed testing requirements and language that you may choose to include in the tender documents to ensure that the desired bioretention soil media mixes are achieved.

1. The vendor must provide a hand-mixed sample of the proposed filter media for analysis. Hand-mixed samples can roughly gauge the proportions of materials required to satisfy the specifications. Depending on the soil manufacturer or vendor, hand-mixed samples may have to be submitted several times to obtain a passing sample. Analytical results must be submitted to and approved by the engineer prior to beginning mechanical mixing operations.
2. Hand-mixing and mechanically mixing filter media are entirely different operations. In fact, it is rare that mechanically mixed samples will meet specifications in the first submission. Media samples from mechanically mixed operations must be submitted for analysis and satisfy the media specifications. To minimize contamination prior to sampling, pass a minimum of 10 m^3 of soil media through the system and properly dispose it. Collect a minimum of three samples from the next 10 cubic metres of material, including one from the bottom of the pile (1-3 m^3 of material), the middle (4-6 m^3 of material), and top (7-10m^3 of material). Approved mechanically mixed samples provide confidence that the vendor can successful produce filter media to the desired specifications.
3. All hand and mechanically mixed samples should be submitted to a certified laboratory. The engineer should assemble a Chain of Custody to detail the required testing and provide it to the contractor. These forms ensure that required tests are performed, and ensure additional quality assurance and quality control (QA/QC). Laboratories provide Chain of Custody forms.
4. Either the contractor or the engineer can obtain media samples. If the contractor is responsible for obtaining samples, provide guidance to ensure the contractor follows QA/QC practices.

5. Engineers should observe the mechanical mixing operations and the source material being used for media development. The contractor must ensure that the engineer has access to the site for sampling.
6. The delivered media should originate from the same location and use the same materials as the approved samples.
7. Media installed without clearance from the field engineer shall be removed at the contractor's expense if the field engineer deems it necessary.
8. The contractor is solely responsible for all required media testing expenses.
9. The contractor is responsible for any delays as a result of testing. No compensation will be provided for delays due to media analysis.

Other testing/submission requirements may include:

- Submit full-size samples of permeable concrete paving units to the engineer to indicate colour and shape selections.
- Submit sieve analysis for grading of bedding and joint opening aggregates to the engineer
- Submit test results from an independent testing laboratory to the engineer to confirm compliance of paving unit requirements
- Include the layout, pattern, and relationship of paving joints to fixtures and project formed details in the tender drawings
- Submit bioswale planting product data including anti-desiccant, mulch, guying assembly, including clamps, collar, guying wire, anchors, and wire tightener in the tender drawings
- Asphalt, porous asphalt, and porous concrete mix records from manufacturer
- Compaction testing of base and sub-base materials

Start testing bioretention soil media early. Using the wrong filter media is one of the main reasons bioretention practices fail. Media testing results can take up to two to three weeks. Start testing early to ensure that the correct bioretention media mix is ready when needed.

Step 5: Outline any maintenance specifications procedures for installation

Any maintenance and decommissioning procedures and requirements should be made available to the contractor and site owner. Maintenance of the LID practices and plant material during and following construction is very important to the success of LID practices. Sediment that is washed into LID practices from construction areas can greatly reduce their performance. Detailed site maintenance and erosions and sedimentation requirements are recommended.

Several examples of erosion and sedimentation requirements preventing contamination from sediment include:

- Final grade to be excavated immediately prior to backfilling with specified aggregate and media to avoid premature facility clogging
- All construction materials are to be stored down-gradient of excavated site whenever possible. Materials stored up-gradient of the excavated site are to be enclosed by appropriate sediment control fencing
- Overland and roof drainage to be directed away from facilities during construction to avoid contamination from fines
- Pipes shall be laid in a true line and gradient on a firm bed, free from loose material. Pipes are not to be laid on soil backfill or in a slurry and are to be securely positioned to avoid displacement before backfilling
- Inside of the underdrain shall be kept clean and free of debris during construction. Remove all debris before additional pipe is installed

Bioretention soil media should be free from contamination from clay, in-situ soils or other debris during construction. All media should be premixed from vendors to optimize quality control between stockpiles and loads delivered to construction sites.

As previously stated, installation, handling, and storage requirements are generally obtained from the landscape designer or architect responsible for the landscaping plan (if included). In addition to specifications, detailed maintenance and warranty clauses will ensure plant material has the greatest chance for survival and establishment.

The warranty on the plant material should state that the plant material will remain free of defects for two full growing seasons from the date of Substantial Completion. The warranty should include the replacement or maintenance of the material during such time. The contractor is responsible for maintenance during the establishment period. This includes the following maintenance operations from time of planting to substantial completion:

1. Water to maintain soil moisture conditions for optimum establishment, growth and health of plant material without causing erosion
2. For evergreen plant material, water thoroughly in late fall prior to freeze-up to saturate soil around root system
3. Remove weeds monthly
4. Replace or re-spread damaged, missing or disturbed mulch
5. For non-mulched areas, cultivate as required to keep top layer of soil friable
6. Apply pesticides in accordance with federal, provincial and municipal regulations and when required by the project manager to control insects, fungus and disease. Obtain product approval from the project manager prior to application
7. Remove dead or broken branches from plant material
8. Keep trunk protection and guy wires in proper repair and adjustment
9. Remove and replace dead plants and plants not in healthy growing condition. Make replacements in same manner as specified for original plants.

Step 6: Outline the payment structure for the installation.

The payment structure for the item to be construction or installed should be detailed. By providing a payment structure for each item, payment certificates will be much easier to assemble and track based on the degree of construction completed up to the issuance of the payment certificate.

For example:

> "Payments made to the contractor under this item shall be compensation in full for all labour, material, and equipment per the applicable unit prices tendered."

Other special provisions

In addition to LID specific special provisions, all other elements of the design including those related to pavement surface works and appurtenances, earth works, miscellaneous items, concrete works, structures, and other items shall have individual special provision sections detailing the information specific to each item. The detail of each special provision items will vary, but should provide all relevant information in order to ensure the products and materials are constructed and installed as desired by the municipality.

9.0 Construction Supervision and Administration

The construction phase is a make-or-break time for LID retrofits. Progress is rapid and the budget is spent quickly. During construction the team often has to make on the spot decisions to deal with unforeseen circumstances. Changes to soil media, permeable pavers, and erosion and sediment control are only a few of the challenges that you may encounter in the field which can impact the success of an LID project.

For these reasons, a professional with LID construction experience (preferably in a ROW setting) should lead the project team. Trained staff and a multidisciplinary team is also critical for a project's success. A team with LID experience can train new staff members and provide informed answers about the project to the public. With the right supervision, administration, and training, teams can overcome and learn from project challenges.

Based on experiences and lessons learned in the field, this section provides an overview of the tasks involved with construction supervision of LID measures, obstacles to good LID construction, and supervision strategies.

Check out the CVC Low Impact Development Construction Guide. The guide has valuable information on construction phase resources, best practices, common mistakes to avoid and other guidance. To download the guide go to:

bealeader.ca

9.1 Construction supervision/ administration tasks

The typical construction supervision and administration activities associated with LID projects are similar to most construction projects. Table 9.1.1 lists the general construction administration and supervision tasks.

Figure 9.1.1: Team members on an LID construction site will include consultants, contractors, and municipal staff. It is essential that team members communicate and are aware of group and individual responsibilities. (Source: CVC)

Table 9.1.1: Typical construction supervision and administrative duties of LID construction projects.

Construction administration	Construction supervision
• Schedule, co-ordinate and attend pre-construction meeting • Prepare construction progress reports • Oversee the day-to-day construction and provide interpretation of the drawings (and supplementary details if required) to the contractor as necessary • Ensure the contractor's methodology complies with requirements of design and review appropriateness of alternative construction methods/approaches • Validate charges for addition or deletions and make recommendations on change orders • Arrange and attend meeting with utility companies • Respond to inquiries and requests for information from external agencies, adjacent landowners, members of the public and staff • During construction, monitor the traffic control measures to ensure they are consistent with traffic control plans and they provide satisfactory levels of safety for workers and motorists. • Notify the contractor of any deficiencies. Perform traffic control/lane closures notifications, coordinating traffic management and public communications with other roadway work in the vicinity. Provide a record of traffic accidents, public notifications and complaints that occur in the work zone • Coordinate all aspects of the construction works with municipal staff. Coordinate with affected utility companies, area businesses, residents, and other regulatory agencies as required • Prepare daily diaries	• Provide full-time site inspection during construction period • Inspect all layout and construction work to ensure compliance with the contract specifications and drawings and works are completed in good workmanship • Provide advice to the contractor regarding the interpretation of the contract drawings and specifications and the preparation of supplemental details, instruction and clarifications as required • Notify the contractor of any deficiencies in the construction of the work, instruct the contractor to take appropriate corrective measures, confirm and report results of the corrective measures during construction • Review, monitor, and ensure compliance with contractor environmental submissions as appropriate in the provisions of the contract document • Enforce the erosion and sediment control plan • Investigate, report, and provide recommendations on unusual circumstances during construction • Prepare progress payment certificates • Record material quantities as they are delivered and as they leave the site • Undertake a complete and thorough inspection of the contractor's work and prepare a list of all outstanding deficiencies at the end of the warranty period and coordinate and ensure that contractor corrects all warranty efficiencies expeditiously and to the satisfaction of the client.

9.2 Construction supervision of LID projects

Just like any type of construction, LID construction is bound to include a few surprises. Whether it is mistakes, conflicts, poor weather, encroachments, or equipment failure, supervisors must address these challenges professionally and efficiently.

The value of construction supervision

Design and construction of LID projects often occur within tight timelines and under limited budgets. It's easy to miss a few details, but the success of LID techniques can depend on those details. For these reasons, it is important that there is sufficient budget is set aside for construction supervision and that supervisors are familiar with LID.

The construction supervisor must learn to quickly recognize and rectify mistakes. Evaluating the work is critical. Supervisors should conduct frequent walkarounds to verify and document critical elements such as grades, invert elevations, and pipe slopes, and installation procedures.

Figure 9.2.1: On-site construction supervisors can verify design elements as they are being built. This perforated pipe will soon be buried. Verifying pipe size, invert elevation, and trench dimensions must occur before the trench is filled. (Source: Aquafor Beech)

Figure 9.2.2: Contractors verifying the location and elevation of bioretention planters during construction at the Elm Drive Project.(Source: CVC)

Since the construction of low impact development facilities is fairly new and many contractors have little to no experience with these types of facilities, having full-time site supervision is recommended.

Supervision strategies

When problems occur, the combination of supervisor and contractor working together is always beneficial. A respectful working relationship is a key ingredient for professional and expedient problem-solving. The construction supervisor is ultimately responsible for enforcing the contract documents and must make decisions based on good judgment.

There are several approaches for addressing on-site problems.

Passive approach: Evaluating the issue of concern and accepting it based on professional discretion. For example, if the issue does not impact the function or integrity of the design, pose endangerment to the public or properties, and/or meets the approval of the owner/agencies, the supervisor may opt to note the change and continue with construction.

Active approach: Actively engaging in the situation to ensure problems are rectified, often enforcing the contractual drawings and documents to their fullest.

Adaptive approach: Making quick decisions on-site. Utilities, encroachments, and weather all cause problems which may require improvisation and quick decisions on design alterations.

With any of these approaches, the construction supervisor must exercise due diligence to ensure that decisions will not have negative impacts. If necessary, the supervisor should consult the owner, agencies, designers and/or superiors for advice and input.

Figure 9.2.3: During the construction of the Lakeview Project the bioswale trench alignment travelled off-centre due to over-excavation. The team lead used the passive approach since the excavation could not be reinstated and the error did not cause negative impacts to the design. (Source: Aquafor Beech)

9.3 Product quality assurance and control

Construction supervisors should document the delivery of materials and products to the site and, as necessary, conduct quality assurance assessments to ensure that all items meet specifications.

To ensure correct materials and products are delivered to the site, request and review product and material specifications, weight tickets, product labels, purchase orders, release forms, and material specification test results. In addition, verify with visual inspections and document with photographs. If materials do not meet specifications, it is important that those materials are flagged and not installed.

Test bioretention soil media!

It is critical that bioretention soil media testing is conducted and that analysis results meet the desired specifications prior to installation. Approved media should also be installed once delivered and not stockpiled on-site as media is easily contaminated during exposure to dust and sediment. Media installation should occur once sources of sediment, such as exposed aggregate road bases, are limited and erosion and sedimentation control measures are installed.

Figure 9.3.1: Construction activities including excavation, sawing, and delivery of materials can cause debris and sediment deposition across a construction site even during good weather. It is essential that bioretention soil media is not delivered and installed until the surrounding area in clean. (Source: Aquafor Beech)

Figure 9.3.2: To the untrained eye both stockpiles of clear stone look similar. An experienced construction supervisor would be able to differentiate the single-washed stone on the right form the double washed on the left. In this case, double washed stone was specified to prevent clogging of the system with stone dust. (Source: Aquafor Beech)

9.4 Utilities

Construction teams will encounter utilities when retrofitting municipal ROWs with LID measures. During construction, supervisors should encourage contractors to proceed cautiously during excavation and ensure that operators have utility locate reports and drawings within them at all times. Supervisors should have a spotter available to daylight utilities by hand when excavation works are within close proximity of utilities.

It is important to remember that locates are estimates. The exact location of utilities must be determined by hand digging or other forms of daylighting. A few general rules when working around utilities are:

- Before exposure, mechanical equipment should not be used within one metre of the estimated utility location.
- Mechanical equipment should not be used within 0.5 metres of the utility until it is fully exposed.
- Once the utility is fully exposed, use hand digging rather than mechanical equipment within 0.3 metres of the utility.

If utilities are damaged during construction and require repair, use the active approach to rectify the damage as soon as possible. Inform the owners of the utilities immediately so they are aware of the damage and can log the incident, and conduct or supervise the repair to satisfy internal procedures and protocols.

In situations where utilities interfere with design components, supervisors often use the adaptive approach. Due to associated construction costs, moving utilities is not usually an option. To accommodate existing utilities, supervisors must employ some ingenuity and make quick decisions. Simplicity and common sense works best for such situations. For example, to avoid an existing gas line during the Lakeview Project, the construction team notched a section of perforated underdrain to allow the gas line to transect the pipe. No design revision or utility construction necessary.

Figure 9.4.1: To prevent damage to pipelines and utilities, daylighting is done prior to excavation with heavy machinery in the vicinity of the utility locate. In this photo utilities are marked with orange paint after being exposed. (Source: Aquafor Beech)

Figure 9.4.2: The costs associated with damage to a pipeline or utility will depend on the type of utility and may include response, repair, environmental impact mitigation measures, and restoration. (Source: Aquafor Beech)

Figure 9.4.3: When utilities are damaged, expect additional people onsite. In this photo communications technicians establish service after damage to a cable at the Lakeview Project. (Source: Aquafor Beech)

Figure 9.4.4: At the Lakeview Project a gas line was found to span the bioswale trench. Moving the gas line was not an option. An adaptive approach using avoidance was determined to be the best course of action. (Source: Aquafor Beech)

Figure 9.4.5: The above photo shows how the perforated pipe was installed around the exposed gas line at the Lakeview Project. A notch was cut in the perforated pipe and fit into place below the gas line. (Source: Aquafor Beech)

Figure 9.4.6: The next step was placing a piece of perforated pipe on top of the gas line to prevent blockages in the pipe when the trench was filled with clear stone. (Source: Aquafor Beech)

9.5 Erosion and sedimentation control

When enforcing erosion and sedimentation control during LID construction, the construction supervisor should always take an active approach. Since many of the design components are sensitive to sediment contamination, supervisors should monitor erosion and sedimentation control measures continuously, ensure proper installation, and request dust control and general site clean-up as necessary.

For boulevard bioretention erosion and sedimentation control measures to prevent contamination of the boulevard bioretention units, you can include:

- Barriers in front of curb cuts to prevent sediment from washing into bioswale prematurely.
- A sacrificial piece of filter cloth on top of the filter fabric-wrapped gravel filled trench to collect dust and debris during construction. The cloth was removed and discarded immediately before the bioretention soil media installation.
- Once all open aggregate works were complete, the bioretention soil media was installed.

Figure 9.5.1: Sediment and dust accumulate quickly on a construction site. Daily cleanup and street sweeping were worked into the schedule at the Lakeview Project. (Source: Aquafor Beech)

9.6 Project certification

Project certification is a critical but often overlooked phase of an LID retrofit project. Project certification verifies that the LID practice has been designed per site drawings before the contractor is released of responsibility. It is the last opportunity to identify and resolve issues as a result of improper construction and/or unforeseen site condition before the long-term site owner takes over maintenance and operations of the practice. Small projects may only require a visual inspection, while a bioretention practice receiving runoff from a large collector road may call for additional data collection like a post-construction survey and water level monitoring.

Levels of project certification

Different levels of project certification protocols can be used to verify the project. There are four levels of certification, with one being the least intensive and four being the most intensive. The level you choose will depend on the complexity of the LID practice.

Level 1: Visual inspection

Visual inspection requires minimal effort and funds, but will not provide quantitative data on the performance of an LID practice. Team members visually inspect the facility and evaluate it using a checklist and design plans. Make sure to complete a visual inspection after a significant rainfall event to confirm water is not ponding for more than 24 hours.

Level 2: Capacity testing

Capacity testing will confirm that a bioretention practice meets minimum design parameters with respect to drawdown time. In addition to the visual inspection, other checks may include a post-construction survey, soil testing and infiltration testing. These tests provide a better idea of whether the practice has the size and soils specified by the engineer.

Level 3: Continuous water level monitoring

Continuous water level monitoring requires loggers to measure both surface and subsurface depths over the course of a monitoring period (at least one year). Water level loggers are easy to use data collection devices that are installed in the practices observation well and can be left for months at a time. The water level data provides a picture of how long the practice takes to drain under different weather conditions and rain events. This level of project certification needs hardware, staffing, and budget considerations from the onset of the project. A precipitation gauge should accompany water level loggers to establish the relationship between rainfall depths and drawdown times.

Level 4: High-intensity monitoring

This level of testing involves flow monitoring and water quality sampling at outlets. This type of monitoring is expensive and requires monitoring experts. This advanced level of monitoring may be appropriate in situations where a new technology is being tested or a technology is being used in a new climate or landuse.

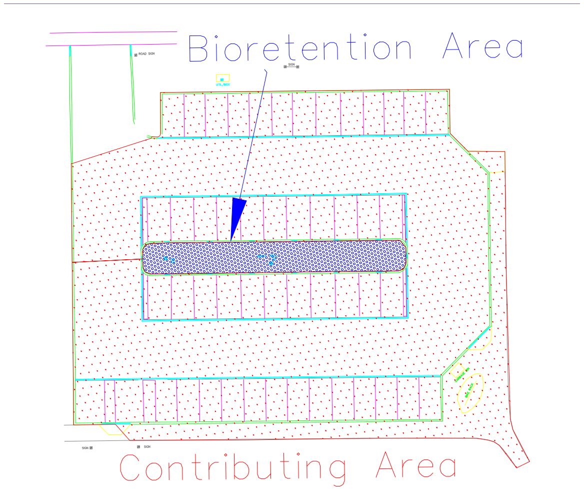


Figure 9.6.1: A post-construction survey provides an accurate measure of the drainage area and size of the practice to compare to the design plans. The survey can also show if there is any problem with stormwater flows bypassing the practice. (Source: CVC)

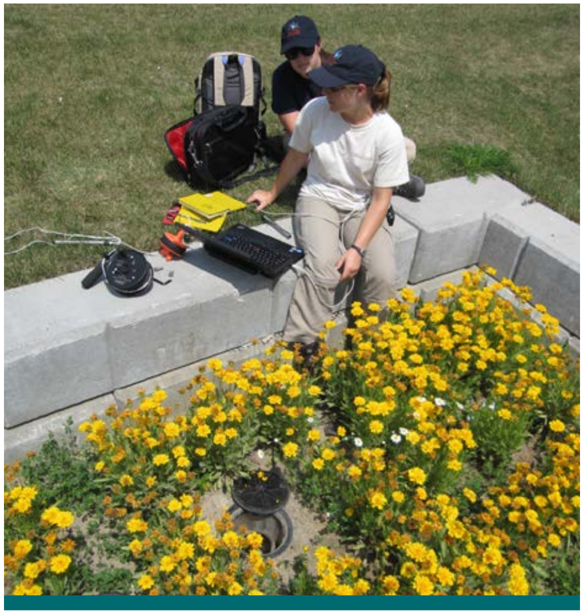


Figure 9.6.2: The water level logger has been pulled out of the bioretention cell observation well. The water level data from the logger is being downloaded directly to a laptop before being put back in the well. (Source: CVC)

9.7 Public interaction

If you're responsible for construction supervision activities during LID construction projects, engage the public and approach local residents and onlookers as much as possible, especially during demonstration projects. An open approach encourages support for LID techniques, and it can make things easier if you run into a construction issue that affects stakeholders.

10.0 Lifecycle Activities

To ensure LID practices function as intended, routine maintenance, rehabilitation, and repairs are required throughout their lifespan. In some cases lifecycle costs may also include expansion of the LID practice. At the end of the project's lifecycle, replacement and disposal must also be considered.

The following sections describe maintenance approaches for LID practices located on municipal ROWs, municipal level of service models, typical activities, and lifecycle costs for LID practices retrofitted within the municipal road ROWs.

10.1 Maintenance approaches for LID practices located on municipal ROWs

To develop an operation and maintenance program for LID practices implemented within the municipal ROW follow these two steps:

Step 1: Establish a maintenance approach that determines the level of maintenance assumed by the municipality and/or undertaken by private land owners. Three common maintenance approaches are detailed in Table 10.1.1.

Step 2: Develop a level of service model which details the maintenance program activities and efforts based on the selected maintenance approach. Evaluation of the maintenance requirements of individual LID practices is required at this stage.

Table 10.0.1: Maintenance approaches for LID practices located on municipal ROWs.

Maintenance approach	Typical requirements /steps	Advantages	Disadvantages
Private owner maintenance	1. Develop/ adopt program documents 2. Develop mandatory maintenance plan 3. Develop homeowner outreach program and materials 4. Develop inspection procedures 5. Establish tracking system 6. Compliance enforcement procedures	Reduced costs to the municipality Provides public education and promotional opportunities within the community	Municipality required to undertake steps 1-6 Policy and by-law revision may be required to allow for private maintenance Long-term maintenance not assured by agreements
Municipal maintenance	1. Collect a detailed inventory of all LID controls 2. Establish maintenance policies 3. Mandatory easement requirement for site plan approval (new development) 4. Train inspectors and approvals staff 5. Develop tracking system 6. Perform and document maintenance activities	Avoidance of enforcement issues, and increased control over maintenance frequency Flexibility to use contractors depending on staff and cost constraints	High costs, extensive staffing requirements and administrative burden
Hybrid	Combination of approaches 1 and 2	Provides maximum flexibility Ability to shift some (typically more frequent) maintenance to the landowner	Responsibilities may not be clear to public

Figure 10.1.1: A photograph showing one the bioretention features in the Lakeview project maintained and even augmented with additional plantings by the homeowner. Private owner maintenance of boulevard bioretention units was found to be a practical approach for the Lakeview project, however, areas where there is a higher occurrence of renters the municipal or hybrid approach may be better suited. (Source: CVC)

There are advantages and disadvantages to each operation and maintenance approach. Adequate training and assembly of maintenance program documents is strongly advised to provide the knowledge required to properly maintain LID practices.

The idea that the public will voluntarily uptake the maintenance of municipal infrastructure may seem far-fetched. However, demonstration projects including the Lakeview Project, identified that homeowners were willing to participate in regular maintenance activities. It suggests that the willingness of homeowners to take ownership of LID measures is possible if the stormwater practices are aligned with the community's vision of their neighbourhood. More details regarding public incentive and engagement methods used during the Lakeview Project are available in the case study located in Appendix C.

More than 60% of homeowners polled for the Lakeview project were willing to spend 2 to 4 hours per month maintaining their boulevard bioretention units. All of the homeowners were willing to spend at least 1 hour per month maintaining these LID practices.

Transfer of resources to LID projects

Regardless of the management model the municipality selects, there is a general requirement for a transfer of traditional stormwater management maintenance resources and funds (outlet inspections, pond dredging, vacuum trucks to empty OGS systems etc.) to a more landscaped based stormwater management maintenance program. Municipalities generally have the required staff, expertise and infrastructure in-house within various departments (e.g. arborist and horticulturalists in parks departments) to manage the maintenance of LID measures. Municipal budgets may need to be re-weighted based on the maintenance efforts required by each department to maintain implemented LID measures.

Level of service models

When developing a maintenance program for LID practices, the development of a level of service model will be required. The following section describes key considerations and approaches in the development of a level of service model to correspond with the selected maintenance approach. Level of service models will detail the maintenance activities and level of effort required. Key considerations include:

- **Frequency of inspections -** annual, semi-annually, quarterly, monthly or complaints driven
- **Scale of implementation -** how will size and number of LID practices effect the program
- **Ownership -** private or public LID practices
- **Maintenance triggers -** complaints driven, emergency driven, inspection driven
- **Risk factors -** flooding, water quality and public safety

Table 10.1.2 illustrates a maintenance program service model matrix. Components and maintenance responses can be scaled as the program matures in response to increasing LID implementation within municipal ROWs. This model allows for minimal upfront investment as demonstration projects are established. Additional tasks and effort are required as projects age and the LID infrastructure system implemented across a municipality becomes more complex. This matrix should be used as a tool to set priorities and plan for future program expansion.

Table 10.0.2: Maintenance program service matrix[85]

Program service level & budget requirements	Elements included in maintenance program	Maintenance task	Maintenance response	Inspectors	Inspection response	Program feedback based on inspection and maintenance experienc
LOWER HIGHER	LIDs on public land and within public ROW + High-priority, high risk, and/or large LIDs on private land with necessary easements and agreements + All or most LIDs on private land within easements and covered by deeded maintenance agreement + Completely private LIDs + All conveyances measures	Repair immediate threats to public health and safety + Repair structural items: erosion, outfalls, clogged or broken pipes + Also include routine maintenance: mowing, weeding, removal of trash and debris, replacement of vegetation + Program includes system to retrofit or reconstruct LIDs	React to complaints and emergencies + Establish schedule for mowing and trash/debris removal + Conduct maintenance in response to inspection reports, checklists, and performance criteria	Rely on owners and homeowner associations to inspect + Public inspectors send report to responsible party + Co-inspections with public inspector and responsible party + System of certified private inspectors with spot inspections and compliance checks by public agency	Complaint-driven + Every 3 years + Annual or semiannual + More frequent for high-priority LIDs	Feedback is anecdotal + Feedback used to modify list of recommended LIDs in design manual based on maintenance burden + Feedback used to modify design standards in manual to reduce maintenance burden through initial design

10.2 Routine maintenance

Maintenance requirements for most LID practices are similar to most turf, landscaped, or natural areas and do not typically require new or specialized equipment[86]. LID techniques, however, are still infrastructure and provide a necessary function that must be maintained. The relative importance of this function requires that maintenance personnel and inspectors are well versed in the design, intended function and maintenance requirements of each system. Just as contractor education is critical to ensure proper post-construction function, the education and training of the individuals servicing LID facilities is vital to their continued operation.

The following sections outline the maintenance requirements for LID practices which should be considered when developing maintenance programs.

Bioretention, bioswales and enhanced grass swales

Bioretention, bioswales and enhanced grass swales share common routine maintenance requirements. Maintenance tasks include:

- Inspections
- Watering
- Removal of litter and debris
- Sediment removal
- Weeding and pruning

Maintenance of bioretention, bioswales, and enhanced grass swales generally involves maintenance of the vegetative cover. Two or three growing seasons may be required to establish vegetation to the desired level. As such, contract documents often specify that the contractor be responsible for undertaking a minimum of two years maintenance. This ensures that the contractor is responsible for the health of the plant material before, during and after installation. Vegetation which does not survive is replaced by the contractor as a condition of the contract documents.

Inspections

Inspections are important to confirm that the LID practice is functioning and to identify maintenance or rehabilitation issues. Regular inspections should be conducted in order to schedule routine maintenance operations such as sediment removal, spot re-vegetation, and inlet stabilization. For the first six months following construction, the site should be inspected after each storm event greater than 10 mm, or a minimum of two visits. If staffing and budget allow, consider scheduling two inspections per year, one of which should occur after snow is melted and ground is thawed. At the minimum schedule annual inspections conducted in the spring of each year. Inspections should also occur after all rainfall events in excess of 60 mm.

During inspections look for inconsistencies in vegetation density, evidence of foot or vehicular traffic through the practice, channelization, erosion, debris accumulation, sedimentation, and structural damage to concrete curbing and condition of pretreatment device.

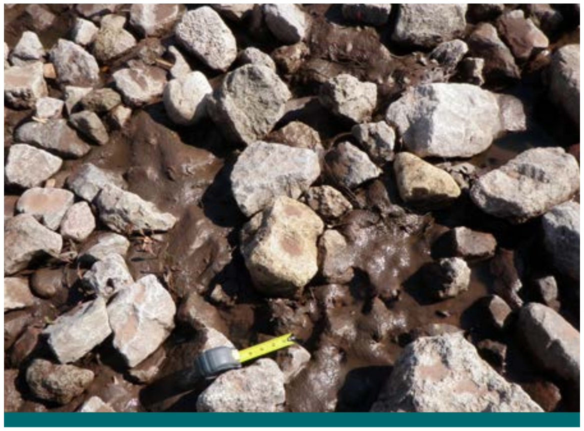


Figure 10.2.1: Closely inspect any pretreatment areas for excessive sediment accumulation from exposed soil during construction. In this photo a riprap spillway between the forebay and bioretention facility has been subject to clay deposition from upstream construction practices. (Source: Aquafor Beech)

Watering

The irrigation of plants is necessary for the first two years or until plants are established. Watering requirements may differ with selected plants but is typically required on a weekly basis during this period. The season between May and August is a critical period for the survival of your plants. During this hot dry season watering should be increased to occur twice a week. When planning watering operations, consider how much precipitation has fallen. During overly wet periods, watering schedules can be modified.

Removal of litter and debris

Trash and debris that has littered the streetscape will be conveyed to and collected in landscaped LID practices. Trash and large debris tends to collect around pretreatment devices and at the inlets of LID practices. Trash may also become stuck in outlet areas affecting the hydraulic function of the facility. The removal of trash and debris should occur at least twice a year but will be heavily dependent on accumulation rates.

At high profile demonstration sites, consider increasing the frequency of trash and debris removal to maintain the desired aesthetic value.

Sediment removal

Pretreatment devices are designed to provide a buffer area where sedimentation occurs before it can reach the vegetated area of the bioretention, bioswale, or enhanced grass swale practice. These areas must be cleaned out before they lose their functionality. Sediment removal techniques will differ by pretreatment practices but may involve hand tools, or high-pressure washer and vacuum trucks. The frequency of sediment removal will also vary depending on pre-treatment practice and catchment conditions. Sediment accumulation should be monitored on an annual basis and conducted as needed.

Weeding and pruning

To maintain compliance with municipal bylaws regarding nuisance weeds and plant growth within the ROW, weeding and pruning will be required. Pruning is typically required only once per year, while weeding may be more frequent dependent on local conditions.

Additional first year maintenance

Bioretention, bioswale, and enhanced grass swale practices are most prone to failure during the first year of establishment. During the first year additional maintenance practices will be required, these typically include:

- Adding reinforcement planting to maintain desired vegetation density. The construction contract should include a care and replacement warranty to ensure vegetation is properly established and survives during the first growing season following construction
- Removing sand that may accumulate on the filter bed surface following snow melt and replacing vegetation that is impacted
- Checking inflow and overflow points for clogging and remove any sediment
- Inspecting grass filter strips for erosion or gullies and reseeding as necessary
- Examining the drainage area for bare soil. These areas should be stabilized immediately. Silt fence or other measures may be needed until the area is reseeded
- Identifying plant material stressed due to salt contamination following the spring melt period and replacing dead vegetation as necessary. (Note: reduce salt loadings from de-icing practices if possible)
- Inspecting overflows to ensure that snow blockages are prevented

Where these problems have been identified during the first year, they should be worked into further annual inspections and maintenance schedules until the issue no longer persists.

Perforated pipes

With appropriate pre-treatment, perforated pipe systems do not require additional maintenance beyond that of a conventional storm sewer. These routine maintenance items include:

- Vacuum debris and litter from catch basins
- Replace damaged or missing grates
- Lawn maintenance

Perforated pipes have been installed in several Ontario communities with high levels of success. Conveyance systems consisting of grassed swales and underlying perforated pipes were installed in Ottawa during the 1980s and 1990s. After more than twenty years of performance, these systems were found to retain their water quality and water balance benefits[87].

More extensive inspection and maintenance efforts occur following public complaints. Subsequent inspection efforts generally involve scoping pipes to located obstructions and debris. Observation ports extending from the surface to perforated pipes or stone galleries should be inspected, if available. Once the problem has been identified obstructions can be removed or dislodged using vacuums or high pressure water sprayers.

If inspections identify problems such as broken pipes, defects or other pipe structure problems full repairs may be necessary.

Permeable pavement

Permeable pavement includes permeable interlocking concrete pavers, pervious concrete and porous asphalt. These surfaces can become clogged with sediment over time, thereby slowing their infiltration rate and decreasing storage capacity[88]. The primary goal of permeable pavement maintenance is to prevent this from occurring.

All types of permeable pavement have initial infiltration rates of hundreds of millimeters per hour, the long-term infiltration capacity remains high even with clogging. When clogged, surface infiltration rates usually well exceed 25 mm per hour, which is sufficient in most circumstances for the surface to effectively manage intense stormwater events[89]. Warning signs of common permeable pavement maintenance issues which must be prevented, addressed or remediated to ensure proper function are identified in Table 10.2.1.

Table 10.2.1: Identifying permeable pavement maintenance issues.

Issues	Identification and action
Slow draining	• Surface should drain immediately. Verify with infiltration testing or observation after rainfall
Ponding	• Rule of Thumb: if more than a nickel deep one minute after a rainfall event, maintenance is necessary • Remove debris and clogging from surface
Surface crusting	• Occurs when sediment accumulates • Remove debris immediately • Increase cleaning frequency of problem areas
Weeds	• Weeds will not germinate without soil and moisture • Removed weeds immediately • Clean out jointing material
Sediment covered joint material	• Identify problem and correct • Clean sediment from joint material
Chips or cracking	• Remove and replace affected paving stones • Saw cut porous asphalt or concrete and replace

Along with maintenance issues identified during inspections, the following items should be carried out for permeable interlocking concrete pavers to ensure the pavement system continues to function:

- Remove debris from pavers following landscape activities with hand blower or mechanical sweeper (as needed)
- Collect debris, dirt, topsoil or mulch which has accumulated within the paver joints and replenish joint aggregate material (as needed)
- Sweep entire paver surface with rotary brush or mechanical sweeper annually and replenish joint aggregate material as required.
- Inspect for potholes, cracked or damaged pavers and remove and replace as necessary (following spring thaw)

Additional preventative activities which will ensure the longevity of all permeable pavements include the following:

Inlet structures: Drainage pipes and structures within or draining to the subsurface bedding beneath porous pavement should be cleaned out on regular intervals[90].

Heavy vehicles: Trucks and other heavy vehicles can compact dirt into the porous surface and lead to clogging. These vehicles should be prevented from tracking or spilling dirt onto the pavement[91]. Signage and training of facilities personnel is suggested.

Drainage areas: Areas contributing to the permeable pavers site need to be mowed and bare areas should be seeded.

De-icers: Non-toxic organic de-icers are preferable and can be applied either as blended magnesium chloride-based liquid products, or as pretreated salt. In any case, all deicers should be used in moderation[92].

Snow plowing: Snow plowing should be done carefully on permeable pavement surfaces by reducing plowing speeds. Operators should be aware of permeable pavement locations and adjust operations as required. Abrasive sands should not be applied on or adjacent to the pavement surfaces[93].

Table 10.2.2 lists preventative and restorative maintenance techniques and equipment for larger scale projects such as roads and parking lots. A preventative maintenance approach removes debris before being trapped within the paving surface and the restorative approach requires more extensive debris removal techniques to restore performance as debris has become lodged in pores and joints of the permeable surface.

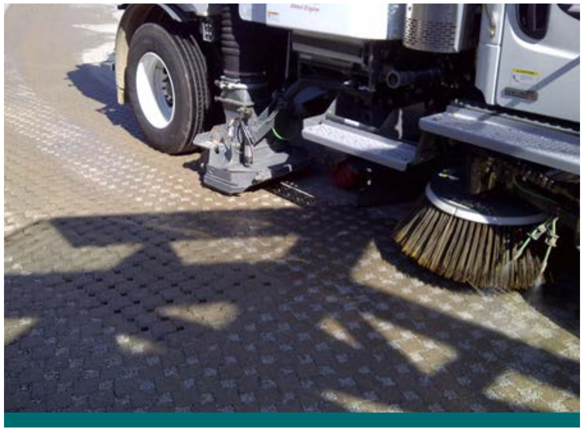


Figure 10.2.2: Vacuum sweepers will remove accumulated debris between pavers, but can also remove aggregate from paver joint (note the voids behind the sweeper truck.) Always replenish any lost joint aggregate following vacuum sweeping. (Source: Aquafor Beech)

Table 10.2.2: Maintenance equipment for permeable pavers.

	Technique	Effect
Preventative	Rotary brush	• Removes debris from joints of permeable concrete pavers and surface of porous asphalt and concrete • Will require slight refilling of permeable concrete paver joint material • May force sediment into pores of porous asphalt and concrete causing clogging
	Broom sweepers	• Typical street sweeper type • Do not use water to clean surface • Best for seasonal cleaning such as fall for leaf litter
	Regenerative air sweepers	• Light duty suction cleaning • Conducive for all types of permeable pavement
Restorative	Riding litter vacuum	• Can be used as a preventative technique • Will evacuate most debris from joint except for aggregate material.
	Vacuum sweeper	• Complete evacuation of joint aggregate material • Replenish removed joint aggregate material • Conducive for all types of permeable pavement
	Pressure washer	• Complete evacuation of joint aggregate material • Replenish removed joint aggregate material • Conducive for all types of permeable pavement

Consult manufacturer's maintenance guide for further equipment details

Prefabricated modules

Maintenance of prefabricated modules such as soil support systems, proprietary oil and grit seperators, or other stand alone stormwater management practices will vary from product to product. All prefabricated products have operation and maintenance manuals from their respective manufacturers which detail specific maintenance and inspection requirements in addition to frequency and costs. In some cases, manufactures will offer to conduct annual inspection and maintenance activities for a nominal fee or offer maintenance training sessions for users. Prior to installing prefabricated modules, research the product's maintenance requirements and offers by the manufacturer with regards to maintenance and training. In general, the following provides relevant inspection and maintenance recommendations for prefabricated modules.

Precast tree planter inspection and maintenance

Similar to bioswales, bioretention and enhanced grass swales much of the routine maintenance activities of precast tree planters revolves around vegetation. All other maintenance issues are generally addressed through annual or seasonal inspections. Table 10.2.3 demonstrates the maintenance activities associated with precast tree planters.

For more information regarding the maintenance and operation activities involved with precast tree planters contact local manufacturers or suppliers.

Table 10.2.3: Maintenance activities for precast tree planters

Maintenance activities		
Regular maintenance	Annual maintenance	Long-term maintenance
• Remove debris and litter from inlets and overflows • Replace damaged or missing catch basin grates • Trash removal • Pruning and Weeding • Weekly watering during first year	• Remove large sediment deposits after spring melt • Mulch removal and replacement • Identify plant material stressed due to salt contamination. Replace dead vegetation as necessary • Add reinforcement planting to maintain desired vegetation density	• Ongoing maintenance and inspections are complaint driven only • Inspect underdrains for clogging and clean as required via vacuum or high pressure water sprayers. • Evaluate soil media for performance. Remove and replace soil media as required

Soil support system inspection and maintenance

Soil support system maintenance activities typically occur as part of other capital work projects in which proposed utilities and associated excavation activities damage the soil support systems. Units should be inspected and those damaged should be removed and replaced.

Annual and routine inspections of these products are not undertaken as the products are buried under a permanent surface treatment such as asphalt or concrete. Any possible deficiency or defects are general noticed as a result of degradation or settling of the surface treatment caused by lack of support provide by the failing support systems. At such time inspection of the units must be conducted by removing the surface treatment and excavating the support system components.

For more information regarding the maintenance and operation activities involved with tree pits contact soil support system manufacturers.

Proprietary stormwater treatment device inspection and maintenance

Proprietary stormwater treatment devices (oil and grit separators or similar devices) may not require annual maintenance. Generally, these devices are inspected on two occasions during the first year to determine oil and sediment accumulation rates. Subsequent inspection schedules are developed based on the accumulation rates. Table 10.2.4 demonstrates the inspection and maintenance activities associated with such devices.

Table 10.2.4: Inspections and maintenance activities of proprietary stormwater treatment devices

Activity	Frequency
Inspect sediment accumulation depths within proprietary stormwater treatment devices or sumps. If approaching capacity limits per manufacturer's specifications (generally 15%) remove via vacuum	Annually or following significant rainfall event (>25mm)
Examine the drainage area for bare soil. These areas should be stabilized immediately. Silt fence or other measures may be needed until the area is reseeded.	Spring (Onset of construction season)
Inspect units immediately after oil, fuel or chemical spill	As needed
Remove debris from inlets, pretreatments and overflows	Annually or following significant rainfall event (>25mm)

Figure 10.2.3: Proper installation of soil support systems ensures settling does not occur and maintenance is not required. (Source: Deep Root,)

Figure 10.2.4: Along with measuring sediment depth in a proprietary stormwater treatment device, check the outlet structure if accessible. If the OGS is functioning as intended, sedimentation should not be occurring. (Source: Aquafor Beech)

Enhanced proprietary stormwater treatment device inspection maintenance

Due to the sophisticated filtering components of such systems, inspections for floatables and debris should be conducted annually and full clear outs should be undertaken every 3-5 years or as needed depending on contaminate loading rates. Similar to typical proprietary stormwater devices, units should be inspected on two occasions during the first year following construction to determine oil and sediment accumulation rates. Subsequent inspection schedules are developed based on the accumulation rates.

Maintenance determination and associated maintenance activities for enhanced proprietary stormwater treatment device are demonstrated in Table 10.2.5.

During Construction: Cover catch basins with geotextile fabric

Examine the drainage area for bare soil. These areas should be stabilized immediately. Silt fence or other measures may be needed until the area is reseeded. Install internal components once the site has stabilized. Housings should be clean prior to installation of internal components to prevent premature clogging.

Table 10.2.5: Inspection and maintenance activities of enhanced proprietary stormwater treatment device.

Issues	Activity
Hazardous material or oil is present	Attempt to manually backwater cartridges or external rinse to regain performance. If unsuccessful replace cartridges.
Greater than 12 inches (300 mm) of accumulated sediment at the bottom of the sump	Removal of accumulated floatable litter and sediment is performed from grade by inserting a vacuum hose or net downward into the maintenance access opening.
3 inches (75 mm) or more of standing water is present in the backwash pool during dry weather	Attempt to manually backwater cartridges or external rinse to regain performance. If unsuccessful replace cartridges.
Excessive floatables and debris are present	Removal of accumulated floatable litter and sediment is performed from grade by inserting a vacuum hose or net downward into the maintenance access opening.
The system has not been maintained for 3 years	Inspect units for performance. If inadequate, attempt to manually backwater cartridges or externally rinse to regain performance. If unsuccessful replace cartridges.

Contact product manufacturers for more specific inspection and maintenance protocols.

10.3 Rehabilitation and repairs

Throughout the lifecycle of an LID practice, rehabilitation and repairs will be necessary. Rehabilitation and repairs occur less frequently than routine maintenance. Issues that require rehabilitation and repairs are often discovered during annual inspections of LID practices. In many cases LID rehabilitation and repairs can be projected based on catchment conditions and observed performance over many years of the project.

In rare cases rehabilitation and repairs are a response to an event that causes damage or reduced function to the facility. Events that may require action include, but are not limited to:

- Spills of deleterious substances upstream
- Failure of pretreatment devices
- Failure of sedimentation and erosion controls
- Extreme weather
- Improper use of the facility (e.g. vehicle used beyond maximum specified load on permeable pavement)
- Change of catchment area use including construction activities

Bioretention, bioswales, and enhanced grass swales

In general, rehabilitation and repair activities regarding drainage and standing water issues are raised by public complaints following rainfall events. Bioswales, bioretention, and enhanced grass swale facilities functioning improperly may require extensive repairs. The following repairs may be needed as determined by annual inspection or public complaints.

Figure 10.3.1: Failure of sedimentation and erosion controls may cause significant impairments to infiltration practices. In this instance, wait until construction has finished before rehabilitating bioretention area. (Source: Aquafor Beech)

Surface cover/media bed: The surface of the bioretention soil media bed can become clogged with fine sediment over time. Core aeration or deep tilling of non-vegetated areas may relieve the problem. The surface cover layer (e.g.,mulch) will need to be removed and replaced every 3-5 years in areas where vegetation has not yet colonized.

Ponded water: If water remains for more than 48 hours after a storm, adjustments to the grading or underdrain repairs may be needed. The surface of the filter bed should also be checked for accumulated sediment.

Figure 10.3.2: Coring has indicated that a layer of impermeable clay has clogged this bioretention unit. Major rehabilitation including replacement of the bioretention soil media will be required to allow for filtration and infiltration. (Source: Aquafor Beech)

Perforated pipes

If inspections identify problems such as broken pipes, defects or other pipe structure problems, full repairs may be necessary. Perforated pipe sections which are damaged should be removed and replaced with new pipe sections. Major repairs of perforated pipe systems are rare and are often a result of poor construction and/or inspection practices during the construction process. Thorough inspections during the construction process should prevent the need for major repairs.

Permeable pavement

Potholes in permeable pavement are unlikely, though settling might occur if a soft spot in the subgrade is not removed during construction. The following provides some general criteria for repairing potholes and broken interlocking concrete pavers[94].

- For damaged areas of less than 5 m^2, it can be acceptable to patch using standard pavement, with the loss of porosity of that area being insignificant. The area can also be filled with pervious mix.
- If an area greater than 5 m^2 must be patched, a permeable pavement similar to the surrounding should be used after approval by a qualified engineer.
- Under no circumstance should the pavement surface ever be seal coated.
- Individual interlocking concrete pavers which are broken or cracked should be removed manually by hand and replace with new pavers of identical design.
- For permeable interlocking concrete pavers that no longer allow for infiltration due to significant joint clogging, remove aggregate joint material with vacuum sweeper and pressure washer then replenish joint aggregate material as specified by paver manufacturer.

Figure 10.3.3: In this photo the aggregate has been removed from permeable interlocking concrete pavers. This will need to be replenished immediately to avoid clogging of the joints. (Source: Aquafor Beech)

Prefabricated modules

If a prefabricated module has stopped functioning before the completion of the expected lifecycle despite manufacturer specified routine maintenance, the best course of action is to identify the failure mechanism via inspection and testing and contact the manufacturer. Common reasons for failure include, but are not limited to:

- Improper installation practices
- Underestimating of the catchment area or expected sediment loading
- Uncertified design modifications by contractors or staff
- A change in, or unexpected, roads operations and maintenance practices in the vicinity of the module
- Neglecting routine inspections and maintenance

In rare cases products may have been supplied in a defective condition. If this is the case, manufacturers may be aware of this and provide a quick fix.

10.4 Replacement and disposal

Replacement of a LID practice is expected at the conclusion of the lifecycle. In some cases replacement may be required before the expected lifecycle is concluded due to significant failures of critical LID practice components.

When a bioretention area, bioswale, or enhanced grass swale no longer functions regardless of routine maintenance, full replacement of plant material, mulch, and bioretention soil media will be required. In instances where concrete curbing or a concrete planter box is used, this may be salvaged if structurally sound.

Despite routine maintenance, permeable pavement systems may require replacement after approximately 30 years due to structural deficiencies. In these cases base and sub-base materials should not require removal and replacement. Instead permeable interlocking concrete pavers, pervious concrete and porous asphalt can be removed and bedding material regraded. Permeable pavement is then reinstalled. Replacement of the permeable pavement and re-grading of the bedding material may also be required if significant hydrologic issues are observed due to improper grading or clogging that cannot be alleviated by routine maintenance.

Perforated pipe systems rarely require complete replacement. Due to their sectional design, broken pipes identified during inspections can be replaced when necessary. When geotextile filter fabric is utilized in a perforated pipe system, this may be the first item that needs replacement.

The materials that cannot be reused onsite during a LID practice replacement often include these items:

Soil and sediment (including media) - testing should be conducted to determine the contents of the sample. An acceptable disposal site will be determined based on provincial guidelines (O.Reg. 153/06) and municipal by-laws pertaining to soil disposal.

Geotextile filter fabric - any filter fabric should be disposed in the same location as the soil sample. In the event that the soil is suitable to be used as fill, dispose of fabric at municipal waste management facility.

Pavement and aggregate - these materials can be recycled by paving or aggregate companies. Prior to removal local pavers should be contacted to arrange pickup.

Plant material - plant material should be composted in accordance with municipal composting programs.

Pipe - pipe may be recyclable, contact local recycling programs to determine appropriate disposal method.

Expansion

A major benefit of LID practices is that they are easily modified to adapt to changing catchment properties and municipal stormwater objectives.

To increase the depth of ponding and create additional storage within a bioretention area, a simple modification is to increase the invert elevation of the outlet or add a hydraulic structure such as a weir or orifice. If such modifications occur across a significant watershed area enhancements to volume control is possible. The storage volume of a permeable pavement system can be expanded in a similar way by modifying overflow pipe inverts or adding hydraulic controls.

LID practices including bioretention areas and permeable pavement systems are inherently scalable. Unlike conventional linear stormwater pipe used strictly for conveyance, soft landscape features including bioretention areas can be expanded by excavating adjacent land or even excavating the existing facility to a greater depth to increase maximum storage capacity during intense rainfall events.

Unlike conventional end-of-pipe measures, LID practices incorporating bioretention soil media can be augmented with phosphorus removal media should phosphorus be identified as a pollutant of concern from the catchment area at a later date.

LID practices are resilient systems. For example, should the underdrain of a bioretention unit become blocked, the system can still provide some runoff detention, filtration, evapotranspiration, and infiltration. Additionally, this blocked underdrain will not affect the function of other LID practices in the area. The modular nature of source controls implemented within a municipal ROW also allows for quick fixes that do not require the entire system to be brought offline, as one would expect with conventional end-of-pipe controls.

The easy expandability and resiliency of LID practices is important as municipalities deal with the need to replace aging stormwater management infrastructure and cope with increased runoff volumes resulting from urban development and changing climate patterns.

11.0 Next Steps and Additional Resources

Now that you have had the chance to read through this document, you should have the knowledge and tools you need to implement an LID ROW retrofit in your municipality. You can:

- Address the barriers to implementing LID in your municipality
- Recognize what options are available to you for LID ROW retrofits
- Know how to determine what LID option is the best fit for your project
- Design a LID ROW retrofit
- Guide a LID project through the approval process
- Supervise the construction of a LID retrofit
- Anticipate the life cycle activities and costs of LID

Whether you represent a small town or a large city, LID retrofits will help to make your community more resilient to extreme weather events. Constructing a LID project will bring economic, social and environmental benefits to your municipality.

Economic benefits

The price tag to bring Canada's aging infrastructure (including water supply, wastewater, stormwater and road infrastructure) up-to-date is estimated to be $170 billion[96]. Implementing a LID ROW retrofit is an economically viable way for your municipality to address issues of aging infrastructure while avoiding costly upgrades. Savings can be found in construction costs, operation and maintenance, and rehabilitation and disposal.

When LID is incorporated into a ROW retrofit, fewer pipes and below-ground infrastructure are installed. LID also reduces the need for site grading and preparation, stormwater drainage infrastructure, and paving. On average, this provides a 25% savings from traditional ROW retrofit projects[97].

Social benefits

LID uses landscaped features to mimic the natural movement of water to manage runoff. These landscapes not only serve functional stormwater management purposes, but also increase aesthetics and provide additional green space for communities. Incorporating an LID retrofit will increases the livability of your municipality.

By providing additional green space and greater aesthetics along the road ROW in your community, you are giving residents the opportunity for healthier life styles. These green spaces encourage outdoor activities such as walking and jogging. More-livable neighbourhoods will also increase property values.

Environmental benefits

As we continue to face challenges brought on by changing weather patterns, municipalities must look at how to construct more resilient communities. LID retrofits are an important step in building this resiliency, protecting against flooding and erosion while improving water quality.

Extreme weather events can happen in large urban metropolises or small towns. No matter the size of the municipality, the effects are equally devastating. Performance studies have demonstrated that LID retrofits reduce the frequency of discharge, runoff volume and peak flows for most storms. Installing an LID retrofit in your municipality will help you to be more prepared for the weather that lies ahead.

Roadways are a significant contributor to urban pollution and installing LID in the ROW is an ideal way to treat this pollution right at its source. Using permeable pavers and bioswales to collect and filter road runoff can drastically improve the quality of water entering ground, rivers, streams and lakes.

Choosing the best option:

Aging infrastructure, flood risk, and water quality are issues facing municipalities across Canada. Every town and city has a unique environment and distinctive challenges. Fortunately, LID retrofit options are numerous and can be tailored to fit the distinctive conditions of your municipality.

By evaluating the specific criteria outlined in Chapter 2 of this guide, you can determine what LID option is the best fit for your municipality. Size of the town or city, experience and skills of municipal staff, budgets, design and intended benefits, are all important factors in choosing the right LID option for your ROW retrofit.

Want to see more real-life examples? Appendix C includes case studies which illustrate the challenges, barriers, and successes of implementing ROW retrofits in a variety of municipalities. This is a great chance discover what you can expect when completing a ROW retrofit through first hand experience.

Maintaining your LID practice

The long-term success of your LID project will depend on its continued functionality and appearance. The key to maintaining your site is keeping up with maintenance practices.

Whether your site is maintained by staff or volunteers, it is likely that it will not always be the same person. Consider documenting your maintenance procedures so they can be easily taught to the next person.

Need more help?

CVC's has a suite of guides tools, case studies and other resources to help you get LID into the ground. Visit:

bealeader.ca

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