Case Study

Elm Drive

Location: Mississauga
Constructed: May 2011

Road Right-of-Way Retrofit

Project Objectives, Design and Performance

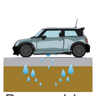
- Road retrofit comprised of six bioretention planters and permeable pavement that treats and infiltrates road runoff on adjacent school property.
- Retrofit aimed at improving stormwater management within the Cooksville Creek watershed by providing enhanced erosion control, quantity control, and water balance.
- Ongoing performance assessment had found that LID practices are exceeding all design expectations, providing 99% total suspended soilds removal and reducing peak flows for 2-year events by 70-100%.

Overcoming Barriers and Lessons Learned

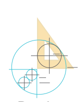
- To provide additional clarity and reduce the potential for error, drawings should include a profile view of the storm services through the bioretention cells, and detailed dimensions of any non-standard items.
- Warranty provisions need to be more specific with respect to LID features (i.e. plant watering and weed-ing) and need to be adhered to by all parties.
- Aesthetics are key - original landscaping had to be supplemented with additional plantings, including trees, to improve aesthetics and add seasonal variety to cells.

Practices Implemented


Bioretention


Permeable Pavement

Barriers & Issues Encountered

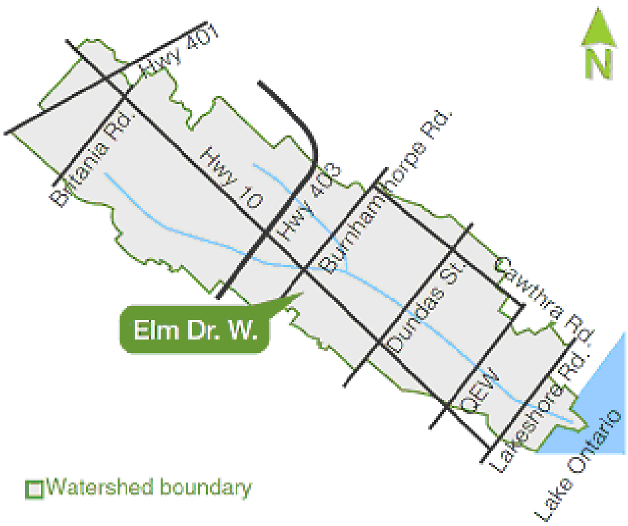

Design


Construction & Comissioning


Operation & Maintenance

Overview

The Elm Drive low impact development (LID) road retrofit is located on Elm Drive West, just south of the Square One Shopping Centre in Mississauga, Ontario.



The street retrofit is located on Elm Drive West in Mississauga, ON, within the Cooksville Creek watershed

The Elm Drive project incorporates both permeable paver lay-bys within the road right of way (on City of Mississauga property) and bioretention planters on the adjoining property owned by the Peel District School Board (PDSB). Runoff flows from Elm Drive West onto the permeable paver lay-by and into to the bioretention planters.

Goals and Drivers

There are several goals and drivers that prompted the LID retrofit of Elm Drive West:

- Ease the burden (runoff volume) on existing municipal storm sewers within the Cooksville Creek watershed
- Upgrading the existing roadway and stormwater management infrastructure from soft shoulders and grass ditches to curb and gutter with modern LID techniques.
- Providing stormwater treatment, thereby improving the quality of stormwater discharged to Cooksville Creek.
- Establishing a LID road retrofit demonstration site that can be used to showcase the effectiveness of LID practices to various Ontario stakeholders
- Providing a site where the stormwater quality control, quantity control and water balance benefits as well as long-term life cycle activities could be assessed under real-world conditions.

Successes

The successes achieved with this project include:

Innovative project – The Elm Drive project is one of the first green street retrofits to take place in Ontario. The LID retrofit improves stormwater quality and reduces runoff at the site.

Joint partnership – A partnership was formed between three stakeholders: the City of Mississauga the PDSB and Credit Valley Conservation (CVC). This partnership allowed the City to maintain the LID infrastructure, part of which is located on PDSB property. CVC provided design, construction assistance and is conducting performance monitoring and maintenance inspections.

Demonstration showcase – The LID features at Elm Drive have been showcased through numerous presentations, events and site tours. These efforts have helped educate numerous stakeholders on the benefits of LID.

Performance – Preliminary monitoring indicates that LID features are performing well, and that for the majority of rainfall events (up to 95% of all events) little to no stormwater runoff leaves the site.

Overcoming Barriers and Lessons Learned

As with any project, there will be challenges faced by the parties involved. The barriers and issues encountered with this project include:

- The preliminary design of the bioretention planters included a ‘flow dissipater’ at the inlet to each planter. Review of the design showed that the flow dissipaters might cause the stormwater to bypass the bioretention media in the planters .
- Grading of the bioretention planters had to take into account matching existing grades at the construction boundaries, as well as working around existing light poles.
- Non-standard right-of-way details had to be used to convey all stormwater runoff to the bioretention planters, as the downstream storm sewer infrastructure provided a constraint to the invert of the storm sewer infrastructure within the bioretention planters.
- The construction drawings should have included additional details, including more dimensions and additional detail information and views.
- The utility locates did not pick up an underground fiber optic cable.

- Trades were unfamiliar with requirements for working with infiltration technologies and in infiltration areas.
- Although plantings meet the requirements of LID functionality, they did not meet the aesthetic expectations of local residents.
- Public safety concerns were brought forward by PDSB. The bioretention planters were a fall safety concern for students and local residents.

The following approaches were used to address these barriers:

- The flow dissipater design was revised to consist of river stone mixed with bioretention soil media to avoid any short-circuiting of the bioretention planters.
- The City of Mississauga and CVC worked with the designer to come up with a non-standard right-of-way design and grading to allow the system to work within all the existing constraints.
- The contractor worked closely with the City, designer and CVC to troubleshoot problems as they arose.
- CVC worked with the City to update landscape plantings were updated, incorporating both trees and shrubs into the bioretention planters which provided additional color, greater seasonal interest, and vertical height.
- Installation of fences around bioretention planters addressed safety concern for students and local residents.

Lessons learned:

- Coordination with all utility companies should be completed prior to the design to ensure all existing utilities are identified.
- Field investigation prior to design is critical. Observing how the site and adjacent areas are used daily will provide critical insight into how the LID feature should be designed (i.e., identify where smokers congregate and avoid installing permeable pavement in these areas).
- Design drawings should be as detailed as possible, including dimensioning of all components and location of all existing utilities and constraints.
- Landscape design plans needs to meet both functional and aesthetic expectations.
- When constructing LID facilities, ensure that an appropriate benchmark is used for surveying to ensure proper and accurate layout.
- Sediment and erosion control guidelines should provide clear guidance for protection of infiltration areas in LID practices and inspectors should ensure that these requirements are being met.
- As LID is a new stormwater management approach for many contractors, it is recommended that municipalities budget for increased site inspection and supervision and construction meetings to address any issues as they arise.

Planning and Regulations

Coordination with project partners, stakeholders, and local Councillors is important with early LID adoption. Prior to and during the design process, project partners worked together to negotiate the terms of the project, including the roles and responsibilities of each party. To facilitate this process, CVC worked with the Ward Councillor and the local PDSB trustee. Support from these representatives helped ensure that the project had buy-in from both City and PDSB staff. It also led to a successful agreement granting the City access to PDSB property for stormwater management and maintenance activities.

Design

Prior to implementing the retrofit project, Elm Drive consisted of a roadway with soft shoulders and a grass drainage ditch.

Elm Drive West pre-development

The stormwater management retrofit was designed to capture stormwater runoff and convey it through permeable pavers and bioretention planters before discharging any remaining runoff to the existing storm sewer system. This was achieved by implementing a road cross-section which is sloped to one side of the road (using a “side shed” configuration) towards the permeable pavers and bioretention planters with all runoff conveyed to LID features via overland flow.

Pre-treatment

Permeable pavement as well as catchbasin sumps and ‘snouts’ are used to pre-treat storm runoff before it is conveyed to the bioretention planters. Permeable pavement filters sediment and debris as runoff infiltrates through a layer of clear stone. Excess runoff is then collected in the catchbasin where debris and sediment is given time to settle out in the sump. The ‘snouts’ are placed on the end of the pipes conveying stormwater from the catchbasin to the bioretention planters. The ‘snout’ prevents floating debris and oils from entering the planters.

Bioretention Planters

Bioretention planters consist of layers of varying types of aggregate. The excavated trench is lined with non woven geotextile and the first layer of aggregate is high performance bedding. There is a 250mmØ HDPE peforated pipe that runs through each of the planters within the first layer of high performance bedding. The bedding is comprised of angular washed limestone free of dirt or small fines.

Perforated pipe covered in high performance bedding

Above the high performance bedding are retaining walls for bioretention planters. Non woven geotextile lines the first layer of the wall. A 150mm thick course concrete sand filter layer is then placed on top, followed by the 450mm filter media mix (sand and mixed organic compost, detailed in the Bioretention Soil Media table).

Bioretention planter with beginnings of retaining wall

Bioretention Soil Media	
Component	**Percentage by Weight**
Sand (2.0 to 0.05mmØ)	85 – 88%
Fines (<0.05mmØ)	8 – 12%
Organic Matter	3 – 5%

Each of the six planters has a catchbasin that empties into the planter through a 200mm corrugated HDPE pipe. Within the planter, there is a 300mm thick layer of 100-150mmØ river run stone on top of a 100mm thick 19mmØ clearstone bed. This layer is placed where stormwater flows into each planter and acts as the flow dissipator and spreader.

Completed bioretention planters, showing flow dissipater (foreground) and salt-tolerant native plants (background)

The flow of stormwater through permeable pavement and catchbasins into the bioretention planters is illustrated in the next figure.

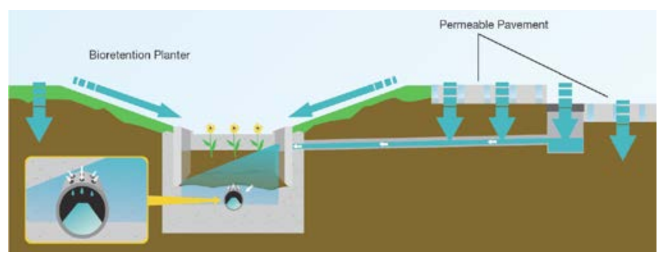


Illustration of permeable pavers & bioretention planter (cross section)

Permeable Pavement

The permeable pavement was installed in the lay-by as well as the sidewalk, totalling an area of 670 m^2. The subbase aggregate is lined in geotextile, contains a 150mmØ subdrain, with a 400mm layer of 50mmØ clear stone, followed by a 250mm layer of 19mmØ clear stone. The setting bed aggregate consists of a 50mm layer of 6mmØ high performance bedding.

The lay-by is a charcoal Unilock Eco-optiloc 26cmx26cm, with 2-5mmØ washed limestone gravel joint aggregate. The sidewalk is a Unilock Eco-priora 12x24cm in herringbone pattern, with 2-5mmØ washed limestone gravel joint aggregate.

Runoff is filtered and dissipated as it percolates through the numerous layers below the pavers. Any runoff from higher flows is directed to bioretention planters through catchbasins and is temporarily stored before discharging to Cooksville Creek.

Completed permeable pavement lay by and sidewalk

Design Issues

The design of the bioretention planters identified a need to incorporate use of a rock flow dissipater where runoff discharges into the planter (shown in the forefront of the *completed bioretention planter* figure). The intention of this dissipater was to slow the velocity of the incoming road runoff and to encourage sheet flow across the planter. However, this feature was placed directly over top of the high performance bedding, creating a path of least resistance directly to the granular material at the base of the planters and permitted runoff to bypass the bioretention soil media and the plants.

To address this issue, some of the soil media in each bioretention planter was raked into the flow dissipation area. The soil media filled the voids in the riverstone, thereby increasing the amount of flow that is directed as sheet flow across the entire planter.

Key Facts

Issues

- Flow dissipaters in bioretention planters initially permitted stormwater to bypass the soil media, preventing the plants within the planters from receiving sufficient water.

Solutions & Lessons Learned

- Bioretention soil media was raked into the flow dissipater to improve flow of stormwater through the entire planter.
- When designing bioretention practices, care must be taken to ensure that there are no means to “short circuit” it. This requires a review of the site grading, slopes and materials used in the bioretention planter.
- Flow dissipaters should not be placed on high permeability materials with direct connections to the underdrains.

For further guidance and LID design best practices, refer to the LID Design Guide.

Construction and Commissioning

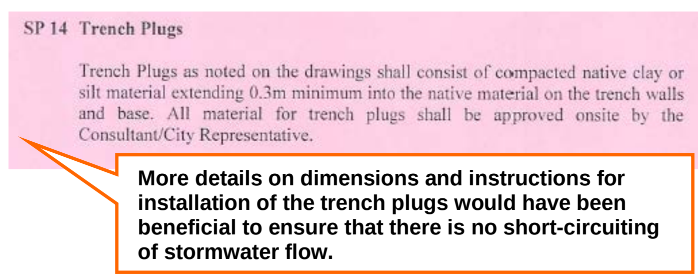
Construction took place over a period of seven months, during which time a variety of issues were encountered by the contractor.

Construction Drawings

A site servicing plan and a site grading plan were provided for the construction of this project. However as this project included several features that the contractor had not previously constructed, additional detail should have been provided on the drawings. To provide additional clarity and reduce the potential for error the drawings should include a profile view of the storm services through the bioretention planters, and detailed dimensions of any non-standard items. While cross sections for the planters were provided, the addition of a profile view would have eliminated the contractor’s confusion regarding the dimensions and layout of the planters. A plan drawing of the planters, with notes on where improvements could have been made is depicted on the next page.

Another issue that arose during construction included perforated and non-perforated pipe segments. While the total length of pipe between manholes was specified, the drawing did not include specific locations and length of the perforated segments, making it difficult for the contractor to judge the actual placement of the pipes. The addition of a profile view of the storm services would have made all lengths and inverts clear to the contractor.

Another issue that was faced was the ‘trench plugs’. The details provided for these plugs in the construction tender, and how they could be improved, are highlighted in the figure below.

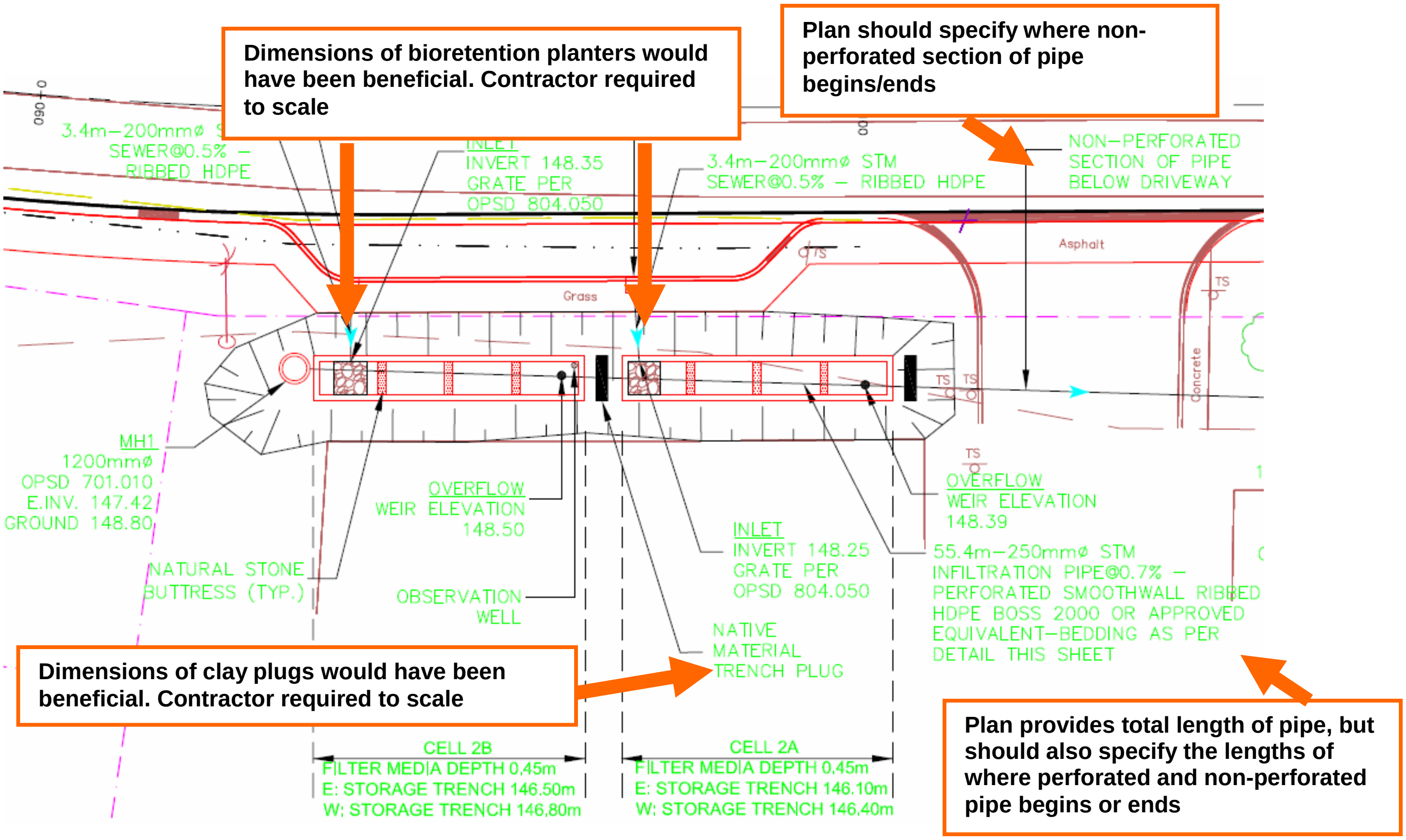


SP 14 Trench Plugs

Trench Plugs as noted on the drawings shall consist of compacted native clay or silt material extending 0.3m minimum into the native material on the trench walls and base. All material for trench plugs shall be approved onsite by the Consultant/City Representative.

Construction inspection & Supervision

During the construction of the bioretention planters there was only part-time site inspection and supervision. However, the construction of low impact development facilities is fairly new and many contractors have little to no experience with these types of facilities. Therefore regular weekly on-site meetings would have ensured that the contractor was clear on the design requirements as the construction proceeds and that any questions or concerns would have been raised and addressed during the construction.



Section of the servicing plan, showing two of the bioretention planters

Future LID projects would benefit from weekly on-site meetings to review the design and direct the contractor on any issues they have. Engineers and contractors are also encouraged to read CVC's LID Construction Guide for further guidance with LID best practices.

Site Layout and Surveying

To minimize errors and keep construction on track, a survey crew should be on site to assist in establishing and confirming elevations. At Elm Drive, surveyors verified the elevations of the inverts of buried pipes to ensure that the correct excavated depth was attained and storage volumes were met.

A curb was used as a benchmark, creating challenges, as the alignment skewed one of the bioretention planters before the oversight was noticed. Care should be given to ensure proper and accurate benchmarks are used.

Erosion and Sediment Control (ESC), and Protection of Infiltration Areas

Protection of the infiltration areas is critical to the success and long term functionality of any LID infiltration project. During construction, bioretention planters were kept offline by protecting the catchbasins connected to the planters. Each catchbasin grate was covered with geotextile and a heavy solid steel plate was placed on top to minimize any stormwater flow into the planters.

Steps were also taken to minimize the interaction of native clay soils with engineered media. Planters were lined with geotextile and a sacrificial geotextile layer was layered on top of the surface. When clay fell in to the high performance material after rain events, the contractor was required to remove them from the bioretention planter.

Working with sub-contractors or material suppliers can also bring ESC challenges. Sub-contractors must be orientated to the site and told the importance of avoiding infiltration areas. During the construction of Elm Drive, a ready mix truck accidently washed out where permeable pavers were to be installed. Since this feature is designed for water infiltration, any concrete below the pavers will significantly hinder its performance. The inspector was notified immediately and reminded the contractor of proper site procedures with respect to equipment cleaning near infiltration areas. Sites where permeable pavers are being installed should have a designated wash out area for cement trucks.

Temporary geotextile placed to prevent contamination

When preparing the tender documents, it is very important to provide sediment and erosion control guidelines with emphasis on protecting the infiltration areas. In addition, a site inspector who understands the need for proper ESC in LID construction should be hired.

Warranty

The warranty is a critical component in the construction of LID features. It provides the project manager with a tool to address any issues during or after construction, prior to assumption. When drafting the tender, the warranty must be as specific as possible in regards to guarantee on work, maintenance and replacement of materials, any associated costs in rectifying deficiencies, and the parties responsible for the work. For example, if the bioretention media needs to be replaced, there are costs associated with plant removal, soil removal, disposal, and replacement. This may require sub-contractors to come back to the site. The warranty should address roles and responsibilities specifically in the tender as outlined in the figure below.

SP 16 Filter Media

Filter media is to be comprised of a mix of organic matter and sand in the following proportions:

85-88% sand (grain size 2.0-0.05mm)

8-12% fines (less than 0.05mm)

3-5% organic matter

Filter media is to remain free from contamination from clay, in-situ soils or other debris throughout the duration of the construction period.

The tender should specify party(ies) responsible for plant soil replacement, if soil was not installed to specifications

Omissions can cause significant delays and increase the overall cost of the project. The Elm Drive project, tender specified the frequency of weeding (once monthly). However, inclusion of a specification for the frequency of inspection of plants or replacement of dead plants would have been beneficial. The figure below outlines the need for maintenance operations from substantial completion but should have included frequency to ensure a functioning and aesthetically pleasing landscape. Aesthetics play a large role in the acceptance of LID by both the general public and decision makers. Replacing plants immediately ensures that the site looks as it was intended.

Maintenance during Establishment Period

Perform following maintenance operations from time of planting to Substantial Completion:

7. Remove dead or broken branches from plant material.

Specification for the frequency of plant health inspections and replacement of dead plants would have provided value.

Once the warranty terms are agreed upon, one of the most crucial parts of a successful project rests on enforcing the terms of the contract. A warranty may be agreed upon by both parties and signed accordingly, however enforcing the items in the contract is a necessary requirement that is often overlooked.

Economics (Capital and O&M Costs)

The costs for the retrofit are provided in the following table.

Capital Costs (including labour and materials)	
Item	**Cost**
Consultant fees	$60,000
Roadwork *(excavation and grading, granular material, hot-mix asphalt & curbs)*	$240,000
Permeable pavement lay-by and sidewalk *(granular material, UNILOCK Eco-Prioria & Eco-Optiloc pavers and curbs)*	$55,000
Storm sewers *(manholes, catchbasins and subdrain)*	$50,000
Bioretention planters *(excavation and grading, planter retaining walls, clear stone, bioretention soil media, landscaping)*	$150,000
Boulevard & miscellaneous *(tree removal, topsoil strip and stockpile, sod, spread topsoil and fine grade)*	$30,000
TOTAL	**$585,000**

Many of the costs incurred with this project are typical for a road reconstruction project where an older road with a rural cross section (with roadside ditches) is converted to a modern municipal road right of way standard. Additional LID elements include the permeable pavement lay-by and side walk, at $55,000, and the six bioretention planters installed at a cost of $150,000. The total cost for the LID elements was $205,000, 35% of the total road reconstruction cost.

Of note from the Capital Costs Table is the low cost of storm sewers for the project. As all of the runoff was directed to the permeable lay-bys via a side-shed slope, the number of catchbasins and length of storm sewer piping beneath the ROW was minimized, reducing construction costs of the retrofit for this item. Costs were further reduced by scheduling the construction of the LID features in conjunction with the road work taking place on Elm Drive W. It is recommended that municipal stormwater managers work closely with other departments to identify opportunities to schedule LID retrofits with other municipal infrastructure upgrade projects as a way to reduce costs.

As with any demonstration project, costs incurred with this project are likely higher than they would be for projects with already established standards and work practices. As consultants, contractors and material suppliers become more familiar with the design and construction of LID practices the costs of LID road retrofits will decrease over time.

As is typical for many demonstration projects, additional unexpected costs were incurred at Elm Drive shortly following construction. The City and the PDSB identified safety issues with the drop in elevation in the planters, necessitating the installation of safety fencing around the perimeter of the planters. The initial planting plan was also lacking in seasonal visual interest, which led to poor aesthetics. A landscape contractor was hired to install the fencing and to augment the plantings to improve aesthetics and safety at the site. The total cost for these items was $30,000. Further details regarding how these challenges were overcome are discussed in the Operations & Maintenance section.

Key Facts

Issues

- Additional detailed dimensions on the construction drawings are required to clarify design requirements and reduce the potential for error.
- A cement truck was observed washing out the remainder of its load in the area where the permeable pavers were to be installed.
- Tender documents should be specific with regards to the degree of maintenance (such as parties responsible, the frequency of weeding, and replacement of dead plants) expected during the warranty period.

Solutions & Lessons Learned

- To ensure sufficient infiltration capacity, cement and adjoining contaminated materials were removed prior to installation of the permeable pavers.
- Education and signage should be provided to ensure that all contractors and sub-contractors are aware of the LID features at the site and the need to keep infiltration areas uncontaminated.
- Surveyors should ensure that proper and accurate benchmarks are used to minimize issues or confusion with surveys during construction.
- Engineering drawings should provide sufficient dimensions, detail views and notes to aid contractors installing LID practices.
- Tenders must include special provisions that address issues specific to infiltration practices/LID – including protecting infiltration areas from contamination and remediation requirements if contaminated; post-construction performance verification and remediation requirements if not performing adequately); and maintenance of plant health and dead plant removal.

Operations and Maintenance

Maintenance

Maintenance is an important aspect in ensuring the proper function of LID practices, particularly during the initial establishment phase. It may be necessary to follow-up with the contractor post-construction to ensure that activities specified within the maintenance agreement are taking place.

In general, it is recommended that the contractor perform the following maintenance operations from time of planting to substantial completion:

- Water to maintain soil moisture conditions for optimum establishment, growth and health of plant material without causing erosion.
- For evergreen plant material, water thoroughly in late fall prior to freeze-up to saturate soil around root system.
- Remove weeds monthly.
- Replace or re-spread damaged, missing or disturbed mulch.
- For non-mulched areas, cultivate as required to keep top layer of soil friable.

- Apply pesticides in accordance with Federal, Provincial and Municipal regulations and when required by the City to control insects, fungus and disease. Product approval must be maintained from the City prior to application.
- Keep trunk protection and guy wires in proper repair and adjustment.
- Remove and replace dead plants and plants not in healthy growing conditions. Make replacements in the same manner as specified for original plants.

Maintenance by CVC staff and contractor staff

One of the key lessons learned from this project is the importance of aesthetics. Initially, each bioretention planter contained only one plant species as the intention was to have one plant species blossom in every season. However, this resulted in the site looking dreary the majority of the time as most planters did not show any colour.

Once the initial warranty expired and plants were replaced as needed, CVC worked with a landscaper that supplemented the original plantings. Increased watering and care has improved the health of these plantings. Plants found in the bioretention planters are as follows:

- 'Franksred' Red Maple
- Peegee Hydrangea
- Bayberry
- Dart's Gold Ninebark
- Black Lace Elder

New fence around bioretention planters and revised plantings

Since safety concerns arose over the winter, trees were planted in the planters to give a better visual indicator of their depth during snow covered months. In addition to the new trees, a fence was erected around the perimeter of each planter for safety reasons. These unforeseen issues arose after the first winter and solutions were implemented immediately the following year.

In order to avoid safety and design issues, a site visit by designers is warranted. This will help them to understand how the site is being utilized on a daily basis. Permeable pavers were installed in an area where students smoke. In the case of Elm Drive this is an issue that a site visit could have managed by possibly considering signage or another deterrent to avoid spent butts fall into the gaps between the permeable pavers, increasing the possibility of clogging and decreasing the aesthetics of the site. Another possibility is to avoid installing LID practices in these areas.

In order to reduce maintenance and operation costs, some contractors wait until the warranty period is nearly complete before they carry out any of the required maintenance. Such practice needs to change as it leaves the aesthetics of the site in poor condition for the duration of the warranty. It also hinders long term plant health and growth.

Signage

As a critical part of educating the public, signage was erected on the property to notify students and general public about the bioretention planters and permeable pavers. Since most of the engineering happens below the ground it is very difficult for the public to visualize and understand the functions of these features.

Signage depicts the bioretention planters (rain garden) and connection with the permeable pavers

CVC used a highly visual approach to give the public a view below the ground without cumbersome displays. Anyone walking by can read the simple text and look through the hole, aligning the real life bioretention planters with the display. They will have an immediate sense of what was engineered below the ground and how permeable pavement was linked to the bioretention planters. Easy-to-understand text was used to ensure that general public could understand it. The term rain garden was substituted for bioretention planters.

Once the signage was installed, students immediately began to stop and read about the features. There was also a notable decrease in the amount of trash being thrown into the planters. The signage helped the students to understand the purpose of LID features and make an emotional connection with them, leading them to care more about the site's appearance and function within their community.

Long Term Performance

Demonstrating that LID works in the real world and provides quantifiable stormwater management quantity and quality control benefits is critical to overcoming barriers and concerns among municipalities, regulatory agencies, developers, businesses and other stakeholders. To help address the concerns and barriers expressed by our stakeholders, CVC is currently undertaking a comprehensive infrastructure assessment at Elm Drive to monitor its performance in managing stormwater runoff at the site. This infrastructure assessment is being overseen by an expert advisory committee consisting municipalities, regional government, the MOE, consultants, and universities.

In December 2012 the advisory committee prioritized study objectives for LID infrastructure assessments. Understanding maintenance and operation requirements and life cycle costs are the top priorities of the stakeholders. These study objectives are directly relevant to effective asset management. Better understanding the performance and stormwater benefits of LID in poorly draining soils, and performance associated with the treatment train design approach were also identified as top study priorities. As Elm Drive includes a treatment train approach, is situated in poorly draining soils, and is continuously assessed for maintenance and life cycle costs, the infrastructure assessment underway at the site is well suited to answering the questions of CVC's advisory committee and our broader stakeholders.

The infrastructure assessment began in 2011 shortly after construction and is now in its third year of monitoring. The assessment involves continuously monitoring precipitation and the discharge from the site (after treatment by the permeable pavers and LID planters. Monitoring staff employ an on-site rain gauge, monitoring wells within the planters, and have equipped a manhole at the end of the facility with specialized equipment to measure the flow, volume and quality of stormwater leaving the site. Flow-weighted water quality samples are analyzed for TSS, and a broad spectrum of nutrients and metals for all events producing discharge. Inflow is estimated by the amount of precipitation and the catchment characteristics of the site. Over the course of the 2011 and 2012 monitoring period the performance assessment has recorded 105 precipitation events. The size distribution of these events mirror historic trends for the region.

One of the first, and very significant, findings from the infrastructure assessment is that a majority of events do not produce any discharge from the site – for these events all runoff is infiltrated on-site. At Elm Drive, events less than 25 mm are entirely absorbed by the system. It is important to note that events of 25 mm or less make up 95% of the total annual rainfall events for the region. See the following figure for further details.

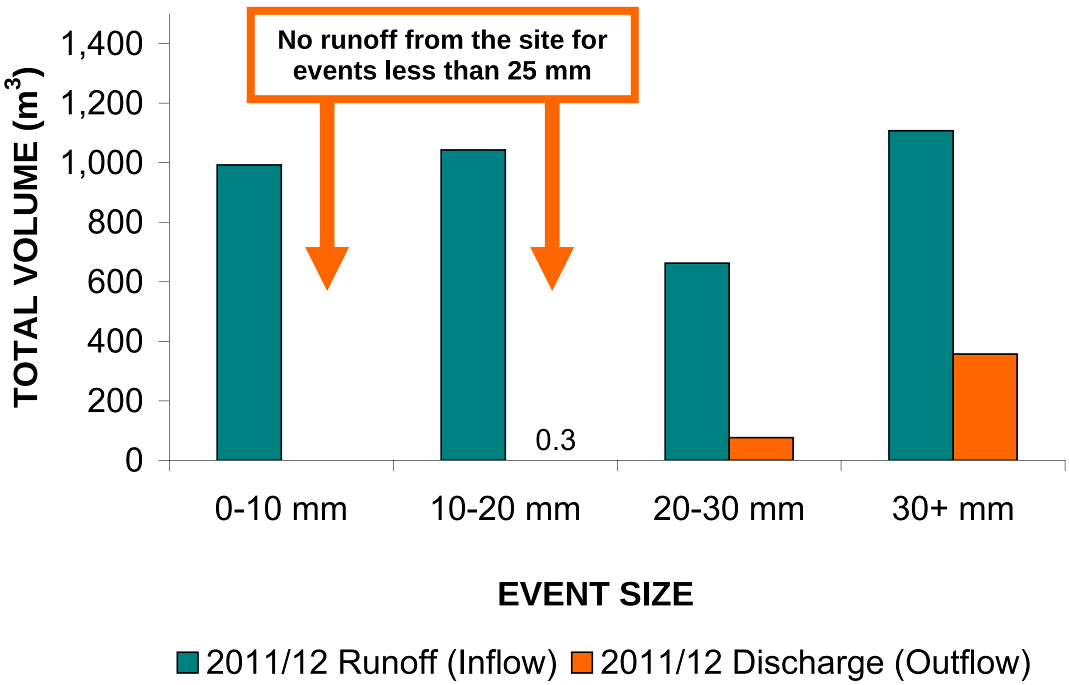


Figure showing the total volume of runoff entering the LID practices at Elm Drive and the measured outflow for the 2011 & 2012 infrastructure assessment period. Flows grouped by size of precipitation event.

Of the 89 events recorded that were 25 mm or less, only one (1% of events) produced discharge from the site. This event was preceded by a larger 30 mm event the previous day. Even with the large preceding event, the volume of runoff leaving the site was still reduced by 60%.

The excellent performance of the LID retrofit at Elm Drive with these smaller, more frequent events, demonstrates that LID can provide excellent erosion control as it goes well beyond satisfying typical erosion control criteria of detaining 5 mm on site. Furthermore, although water balance objectives were not a design objective for the Elm Drive retrofit, the groundwater recharge is estimated to be at least 11 mm for all events, which surpasses the typical stormwater criteria of 3 mm per event.

Infrastructure assessment has also determined the extent to which the LID retrofit provides peak flow control. Two storms comparable to the 2-year return storm have been observed at Elm Drive since monitoring began. Peak flow was reduced by 70% and 100% for these events compared to pre-retrofit conditions. In fact the entire volume was retained on site for one of these events.

An event for which an 85% peak flow reduction was observed is illustrated in the following figure. For this event, volume was reduced by 50%.

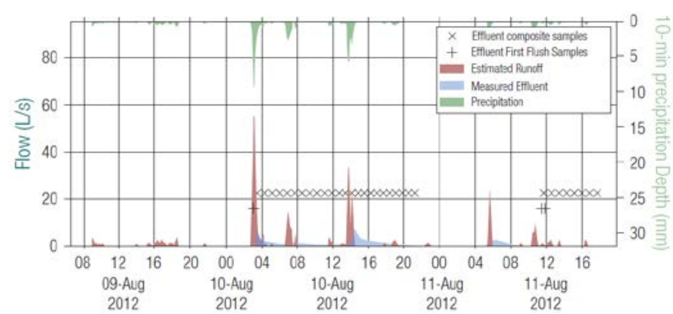
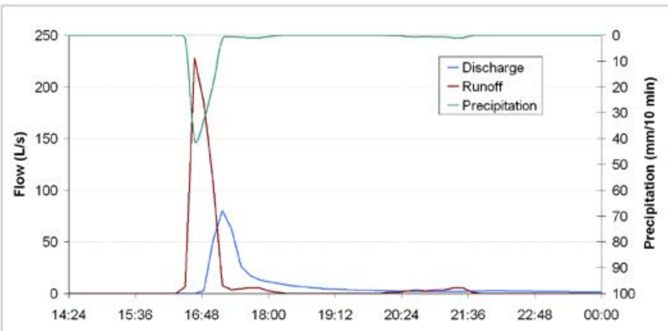


Figure showing the flow entering the LID practices at Elm Drive and the measured reduction in peak flow from the site for a 56 mm rainfall event over a two day period.

From the results of these (and numerous other) events, it is clear that Elm Drive is providing strong site level control.

Events much larger than the 2-year storm have also been recorded at the site. On July 8, 2013 a short duration high intensity rainfall event centralized over parts of Toronto and Mississauga was observed. A rain gauge located at the Elm Drive recorded 104 mm of precipitation over a five hour period, with a 240 mm/hr peak intensity over a 10 minute interval. Preliminary analysis indicates that this storm event exceeded the 100-year design storm.

The following figure demonstrates how the system performed during this extreme event.



Estimated runoff compared to measured discharge from the Elm Drive site during July 8th storm event (104 mm of rain over 5 hours)

Preliminary data analysis suggests that the LID practices at Elm Drive provided both peak and volume reductions as well as a 40 minute lag time until discharge was observed from the site. These performance findings further illustrate that even in extreme cases, the LID treatment train approach utilized at Elm Drive (and the appropriate native soil conditions) can reduce the burdens on municipal storm systems.

In addition to observing water quantity, quality is also being monitored at the site. Any discharge from the site is sampled and analyzed for TSS, nutrients and metals. Due largely in part to the volume reduction performance, contaminant loading is reduced considerably. 99% of all TSS is removed greatly exceeding the MOE enhanced treatment requirements of 80% removal. The TSS concentration is also below Provincial Water Quality Objectives indicating that discharge from this site does not negatively impact the receiving aquatic environment.

Parameter	Typical Residential Uncontrolled **Concentration** NSQD	Typical Bioretention Effluent **Concentration** BMPDB	Elm Drive Median Effluent **Concentration**	Estimated **Load Reduction** (Accounting Volume Reduction)
Cd µg/L	0.25	0.79	0.09	**94 %**
Pb µg/L	6.00	1.98	0.92	**99 %**
TKN mg/L	1.29	0.64	0.70	**94 %**
TP mg/L	0.27	0.14	0.06	**98 %**
TSS mg/L	**61**	**8**	**14**	**99 %**

Water quality benefit is considerable with the mass loadings of all above contaminants being reduced by more than 94%

To ensure that the infrastructure assessment provides comprehensive data regarding the long-term operation, maintenance and life cycle activities for LID practices, monitoring at the site will continue for an extended time period. Long-term assessment work currently underway includes site inspections and maintenance reports, which will be published to support the needs of our stakeholders.

For further information and monthly updates on the ongoing infrastructure assessment work being undertaken at Elm Drive visit CVC's Elm Drive website or visit bealeader.ca website to access CVC's suite of LID guidance materials.

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