Clean-water Technology

Low-impact development coming to a neighbourhood near you

By Alisha Chauhan, B.Sc., Robb Lukes, PE, M.Sc., Christine Zimmer, M.Sc.(Eng.), P.Eng., and Jakub Wrobel, H.B.Sc.

Low-impact development (LID) is a holistic approach to stormwater management. This clean-water technology has demonstrated both aesthetic and economic benefits;[1] it mimics the natural water cycle to manage stormwater close to where it falls.

More developers, architects, and contractors are adopting LID practices in their developments to effectively manage stormwater onsite. This helps reduce infrastructure costs and offers unique green urban landscape features to their customers.

Stormwater management's evolution to LID

The International Joint Commission (IJC) has long recognized the need for stormwater management to protect water quality and biodiversity of the Great Lakes. The Great Lakes Basin is the largest freshwater ecosystem in the world, and contributes billions of dollars in gross domestic products (GDPs) and fisheries annually to the economies of Canada and the United States.[2] It is a valuable water resource and economic asset providing livelihood to more than 40

The green street project at Elm Drive in Mississauga, Ont., has low-impact development (LID) practices that clean water naturally. This project consists of bioretention planters and permeable pavement that work together to slow, filter, and clean stormwater on its way back to Cooksville Creek and Lake Ontario.

This photo shows before construction where poor stormwater drainage is going through a grass ditch.

million people. Protecting this basin through innovative stormwater management is a priority.

Stormwater management is an evolving science across Ontario, visible in neighbourhood developments as in-the-ground practices reflect the year the development was built. Before the 1970s, urban stormwater was directed through sewers to receiving waterways without treatment. During the 1970s and early 1980s, stormwater management concerns consisted of controlling peak flows or flooding.

Since the 1980s, stormwater management has evolved from the typical end-of-pipe stormwater management ponds—designed to remove up to 80 per cent of suspended solids from runoff and peak flows—to LID at site. One reason this shift occurred is recent literature, site-monitoring, and provincial initiatives suggest the end-of-pipe approach is not sufficient to reduce erosion and protect water quality. Low-impact development is being applied in Ontario, British Columbia, Alberta, United States, Australia, and Europe.

Enhancing the bottom line

LID practices serve as an economic means of meeting water quality and erosion objectives through implementing:

- vegetated roofs;
- permeable pavement;
- bioretentions;
- harvesting of rainwater; and
- bioswales.

Low-impact development complements and meets municipalities' green development standards and stormwater management and provincial planning requirements.

An integral component of LID practices is landscape design, which improves aesthetics and raises property value while increasing public enjoyment. LID provides stormwater management options that optimize urban form to allow for greater developable space and added value for customers. Development with LID has had an average reported savings of 24 per cent compared with buildings that use conventional stormwater infrastructure.[3]

Implementing LID features within a Brampton, Ont., community allowed Sequoia Grove Homes to reap benefits, explains principal Giulio Bianchi.

"First, we have avoided the need for a stormwater pond onsite, thereby increasing the number of developable lots within the community," he says. "We were also able to provide homeowners with unique landscaped features, including 'bioretention' planters within road right-of-ways in the western portion of the site and a large planted bioretention swale on the eastern portion."

Despite the province's early recognition of LID practices in 1991, its application has been limited to demonstration sites scattered throughout Ontario. In an effort to promote innovative technologies on a wide-scale basis, the province has provided $17 million to communities across Ontario. Additionally, to transfer knowledge and encourage innovation in watershed management, Credit Valley Conservation (CVC) and Toronto and Region Conservation Authority (TRCA) have received funding to develop guidance on LID design, construction, and maintenance.

CVC: a leader in LID

In 2010, CVC and TRCA published *LID Stormwater Management Planning and Design Guide*, as it had become apparent supplemental guidance and training was needed to target the construction industry. LID is a new form of stormwater management and urban design for Ontario, and many engineers and contractors are unfamiliar with how to properly construct these systems.

Unlike end-of-pipe controls, LID practices are an integral part of the urban form and require a different approach to construct. Low-

Bioretention planter construction underway—this photo shows the installation of retaining wall and high-performance bedding.

For the permeable pavement installation above, aggregate layers and high-performance bedding were specified.

impact sites require attentiveness throughout the construction process as to location, intended function, and protection from sediment-clogging and over-compaction. The stabilization of the contributing sub-catchment becomes critical to the success of LID features, as is their unique outlet configurations and specified materials.

The Center for Watershed Protection (CWP), based in Ellicott City, Md., conducted a survey of 72 LID practices in Southern Virginia's James River Watershed. Each of the LID practices as constructed was compared to the municipally approved stormwater design plan. The evaluation found 47 percent were observed to have one or more deviations from the site plan, many in ways that significantly impaired the required performance.[4] The most common deviations were:

- poor vegetation coverage and health;
- missing or improperly constructed pre-treatment devices;
- undersized retention and detention volumes;
- soils clogged with construction sediment, are compacted, or do not meet specification; and
- inlets and outlets incorrectly constructed, resulting in flows bypassing or short-circuiting the practice.

This knowledge gap has been apparent in CVC's own experience in the early implementation of LID projects within the Credit River Watershed. Several LID projects have required post-construction repairs to correct inlet and outlet invert elevations, replace engineered soil that did not meet specification, and re-grade blocked or bypassed inlets. If sound LID designs continue to be improperly constructed, LID will get a poor reputation among the public and decision-makers. Therefore, it is critical that contractors and inspectors understand the purpose of LID practices as a new form of stormwater management.

Guidance and training

In 2010, a CVC-led partnership initiative was launched to develop guidance and training to educate the construction industry. As a first step, CVC has created two LID construction guides with a team from a LID construction firm in the United States—Emmons & Olivier Resources Inc.—as well as an experienced Ontario firm—Sabourin Kimble & Associates Ltd.

The *LID Construction Guide* assists engineers, project managers, and site supervisors in translating LID designs into plans, specifications, and in contract documents to ensure practices are properly constructed.[5] The *Contractor's and Inspector's Handbook to LID Construction* is an illustrative and condensed version of the *LID Construction Guide* and is intended for the contractor and inspector on the project site.

While many jurisdictions in North America have developed LID design guidance, none have developed educational material directed toward the issue of LID construction. This guidance has already been picked up by stormwater project managers in California, Minnesota, and Germany wishing to educate their contractors on proper LID construction.

The content of these guides was the basis of a training program for construction professionals—LID Construction Workshop for Engineers and Contractors—offered earlier this month as part of the annual Making it Work LID Conference.[6] A steering committee of stakeholders from the province, conservation authorities, municipalities, construction firms, design firms, and developers has helped shape the content of the guidance and training workshop.

Communication is key

Communicating the LID purpose, along with the design and construction steps, is critical. This needs to happen at pre-bid meetings, pre-construction meetings, weekly construction meetings, and particularly during hand-off moments between contractors and sub-contractors.

Through the authors' experiences, CVC has found it necessary to clearly communicate the design to the contractors during the step-by-step implementation process. One consideration to ensure clear communication is developing clear, thorough specifications to prevent construction error to the maximum extent. Another important consideration as the construction process moves from excavation to final landscaping and stabilization is simple verbal communication of critical specifications and information. For the contractor or inspector for which LID is a new concept, stringent supervision by engineers is key. This allows the contractor to ask questions and have them instantly addressed rather than continuing construction based on assumptions.

Grading: a sub-base for permeable pavement lay-by and sidewalk.

Tendering for success

A mandatory pre-bid meeting that includes outlining the project's unique LID aspects have been successful in attenuating non-serious bidders and attracting many qualified contractors to the project. Other useful methods to obtain experienced bidders include using a pre-qualification process and requesting prime contractors to furnish a list of projects completed with references.

Many times, binding construction and plant installation along with landscape establishment responsibilities—which can extend years beyond construction—has proven to be a logistical headache for both the owner and contractor, given sureties and payments are strung over this period. Often, writing a separate specification and contract for the construction and landscape establishment is beneficial. The landscape establishment contract typically runs two to five years after completion and can cover planting, establishment (including watering as necessary), plant material warranties, and maintenance of the practices.

Since there are always unforeseen construction conditions and badly timed storm events, a separate line item in the construction documents for emergency erosion control is one strategy to ensure erosion control is performed properly and contractors are paid for their additional work. This helps protect the owner because the contractor has little reason to avoid addressing erosion and sediment control issues as they arise if they know they will get paid for proper work performed.

Verifying design assumptions

Physical site inspection by engineers during design and construction is an overlooked aspect of LID. In addition to field-verifying assumptions of underlying soils, infiltration rates, and site drainage patterns for design, it is also important for the design conditions to be confirmed at construction by qualified engineers.

For example, an infiltration design may depend on excavation to a more permeable soil layer; in this case, the geotechnical engineer should provide sign-off to ensure the contractor has excavated to the appropriate soil layer.

The secret is in the soil

A critical, yet often misunderstood, component of bioretention practices is the engineered soil. This performs the role of filter, subsurface storage, and vegetation support. A leading cause of bioretention failures is soils too high in clay content. A strategy for getting the right soil to the site is providing a clear specification with desired grain size distribution and organic content. Suppliers new to mixing this type of soil must be informed well in advance of delivery as testing and refining a mix may take several weeks to months. Additionally, the construction documents should clearly state no bioretention soil should arrive onsite until the supervising engineer has received a satisfactory soil analysis report confirming the soil meets specification.

More than pipes and aggregates

Many LID practices involve use of vegetation, and planting design and establishment is an often overlooked component. These practices are different from conventional large end-of-pipe practices like stormwater ponds in that they are integrated into the urban form. They are located on private property, within right-of-ways, and in public landscaped areas. Therefore, plant selection and planting plans for these practices are essential both for function and for public perception and acceptance of LID practices in the landscape. Plants chosen must not only serve the stormwater treatment, evapotranspiration, and infiltration functions, but also be able to thrive in the unique hydrological conditions of LID and fit urban landscape aesthetic standards.

Whenever possible, vegetated LID practices should be kept offline for at least the first year. This allows time for young plants to establish and fully vegetate the practice without being washed out or drowned. An offline practice is where the inlets can be closed or blocked off and stormwater flows can bypass the system. When placing a system offline is impossible, large mature plant stock should be used.

Notes

[1] See Dr. G. Krantzberg's "A Valuation of Ecological Services in the Great Lakes Basin Ecosystem to Sustain Healthy Communities and a Dynamic Economy," prepared for the Ontario Ministry of Natural Resources in 2006.

[2] See Martin Associates' 2011 report, "The Economic Impacts of the Great Lakes–St. Lawrence Seaway System."

[3] For more, see the United States Environmental Protection Agency's (EPA's) 2007 report, "Reducing Stormwater Costs through LID Strategies and Practices."

[4] See David Hirschman and Laurel Woodworth's 2010 article, "Design, Construction, and Maintenance of LID Practices: Results from a Field Assessment in Virginia's James River Watershed" from *Low-impact Development 2010: Redefining Water in the City ASCE Conference Proceedings.*

[5] Visit www.creditvalleyca.ca/lid-construction-guide to download a copy of the *LID Construction Guide.* For CVC's LID Guidance

Elm Drive: A Green Street Project

A road reconstruction project presented a great opportunity to improve stormwater management through implementation of low-impact development (LID) in the Cooksville Creek watershed of Mississauga, Ont.

Shown on page 20, the road's right-of-way in front of the Adult Education Centre at Elm Drive—constructed within seven months and completed in June 2011—now hosts a demonstration green street project comprised of LID practices. These practices consist of permeable pavement lay-bys within the right-of-way directing excess stormwater flow into adjacent bioretention planters spanning school and city-owned property. Monitoring results show a marked improvement in water quality and volume control. Runoff volume from a two-year return storm has been reduced by 78 percent.

Integrated design

Communications and partnerships remain critical to all aspects of successful LID practices, and the unique attributes of this public site with the school property being adjacent to the road right-of-way resulted in a unique partnership among CVC, the city, and the Peel District School Board (PDSB).

The facilitation of an integrated design entailed negotiation of terms, roles, and responsibilities among partners. Terms agreed on during negotiations included granting Mississauga use of PDSB property for stormwater management purposes as well as construction and maintenance of the LID features.

It is what is underneath that counts

Stormwater runoff from the roadway flows into the permeable pavement and infiltrates through aggregate layers to the perforated pipe subdrain into bioretention cells or directly into the subsoil. The permeable pavement section (*i.e.* lay-by and sidewalk) comprises an area of 670 m² (7212 sf) of green street and consists of interlocking concrete pavers with 6 mm (0.25 in.) narrow spacings allowing stormwater through them. The joint spaces are filled with a crushed angular chip stone rather than the sand typical for non-permeable paver applications.

Underneath the interlocking pavers are three layers of different-sized aggregates to treat stormwater:

- 50 mm (2 in.) bedding layer of 6 mm diameter clear stone;
- 250 mm (10 in.) base layer of 19 mm (0.75 in.) clear stone; and
- 400 mm (16 in.) subbase layer of 50 mm diameter clear stone.

A drainage fabric geotextile prevents soil from migrating into the base by separating the subsoil from the subbase. Clear stone, free of fine particles, avoids clogging subsoil or geotextile fabric and allows for temporary storage of stormwater in the pavement structure. From the aggregate layers, any stormwater that does not soak into the subsoil enters the 150 mm (6 in.) diameter perforated subdrain located under the lay-by and connects to the bioretetion planters.

A series of bioretention planters

Stormwater runoff is detained and treated in a series of bioretention planters connected to each other by a perforated pipe. Runoff is piped to the planters after flowing through permeable pavement and catch basins.

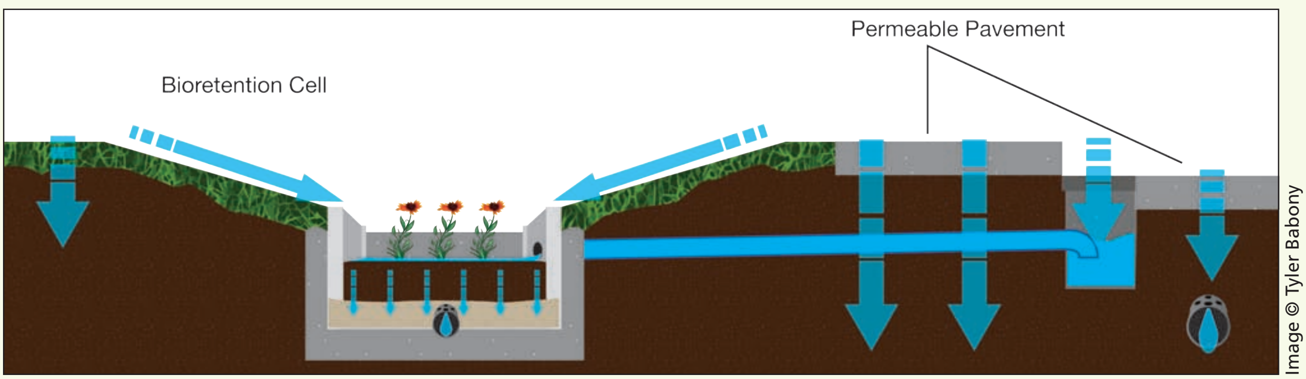
The seven bioretention planters consist of varying aggregate layers, engineered soil, plants, and a perforated pipe. Each one is about 32 m² (345 sf) and excavated to a depth of 2 m (6.5 ft). The excavation is lined with geotextile drainage fabric backfilled with 1 m (3.25 ft) of 19 mm (0.75 in.) diameter angular washed limestone also known as high-performance bedding. A 250 mm (10 in.) diameter high-density polyethylene (HDPE) peforated pipe runs the length of the series of planters within the high-performance bedding.

The retaining walls for the bioretention planters and a 150 mm (6 in.) thick course concrete sand layer sit above the high-performance bedding. This is followed by a 450 mm (18 in.) bioretention filter media mix primarily comprised of sand, some fines, and three to five per cent of organic matter. The planters are planted with species that can serve the stormwater function and also provide colour and a year-round aesthetic.

Long-term performance

Preliminary monitoring of rainfall events during 2011—ranging from 1.6 to 45.6 mm (1/16 to 1.8 in.)—showed events smaller than 13 mm (0.5 in.) have had little to no discharge to the storm sewer. This indicates runoff was either infiltrated or lost through evapotranspiration. Larger events (>13 mm) also showed a delay in the time to peak in outflows from the planters. Through its Stormwater Management Monitoring Program, CVC began monitoring at Elm Drive in September 2011.*

** For additional information on the Elm Drive green street project, visit www.creditvalleyca.ca/lid-elm-drive.*



Mississauga's green street project on Elm Drive's cross-section shows the stormwater flow draining into a catch basin in permeable pavement connected via piping to a bioretention cell with underlying perforated pipe.

toolkit, visit www.bealeader.ca.

[6] Since 2008, Credit Valley Conservation (CVC) has held yearly Low-impact Development (LID) Leaders in Action conferences to educate stakeholders involved in LID implementation. To download presentations from CVC's LID conferences, visit www.creditvalleyca.ca/lid-events. For more on various in-the-ground LID projects, visit www.creditvalleyca.ca/green-projects-map.

Alisha Chauhan, B.Sc., has been with Credit Valley Conservation (CVC) as a water resources specialist since 2008. As part of CVC's Water Protection and Restoration Team, she works as a technical writer to communicate and promote the team's sustainable technology projects to various stakeholders including community and government. Chauhan obtained her bachelor of science in biology and professional writing at the University of Toronto (U of T). She can be contacted via e-mail at achauhan@creditvalleyca.ca.

Robb Lukes, PE, M.Sc., has been with CVC as a sustainable stormwater management specialist since July 2009. His primary focus is on developing guidance, training, and demonstration projects for low-impact development (LID), and he also reviews new development and redevelopment stormwater management plans for consistency with CVC policy and LID initiatives. Lukes has degrees in water resources management from the University of Wisconsin (UW) and civil and environmental engineering from the University of Portland. Before joining CVC, he worked as an environmental engineer for the Low-impact Development Center in Beltsville, Md., where Lukes produced original research through stormwater modelling, project evaluation, and reviews of stormwater policy. He can be reached via e-mail at rlukes@creditvalleyca.ca.

Christine Zimmer, M.Sc.(Eng.), P.Eng., is the manager of water protection and restoration for CVC. She is responsible for developing tools, guidance documents, and providing assistance to stakeholders implementing LID practices in both new and existing urban areas. Zimmer and her team are also responsible for in-stream real-time water quality monitoring and monitoring of innovative stormwater technologies. Before starting at CVC, she obtained a master's degree in water resources engineering from the University of Guelph. Zimmer was part of a research team funded by the Ministry of Environment and International Joint Commission (IJC) on LID. She can be contacted at czimmer@creditvalleyca.ca.

Jakub Wrobel, H.B.Sc., has been a water resources technician at CVC since 2008. His responsibilities include leading construction site supervision, documentation, and monitoring for various LID projects in co-operation with contractors, consultants, municipalities, educational institutions, and the government. Wrobel is also involved in education and outreach activities that target youth to teach them about their local environment. Before starting with CVC, he earned an honours bachelor of science in environmental management and geography from U of T. Wrobel can be reached at jwrobel@creditvalleyca.ca.

At a site tour of the Elm Drive, Mississauga green street, municipal, development and construction trade professionals learn first-hand about various LID features including permeable pavement constructed over lay-bys adjacent to a series of bioretention planters. A unique partnership between Credit Valley Conservation, Peel District School Board and the City of Mississauga is a key factor at this site where stormwater runoff volume from a two-year return storm has been reduced by 78 percent.

CVC Credit Valley Conservation