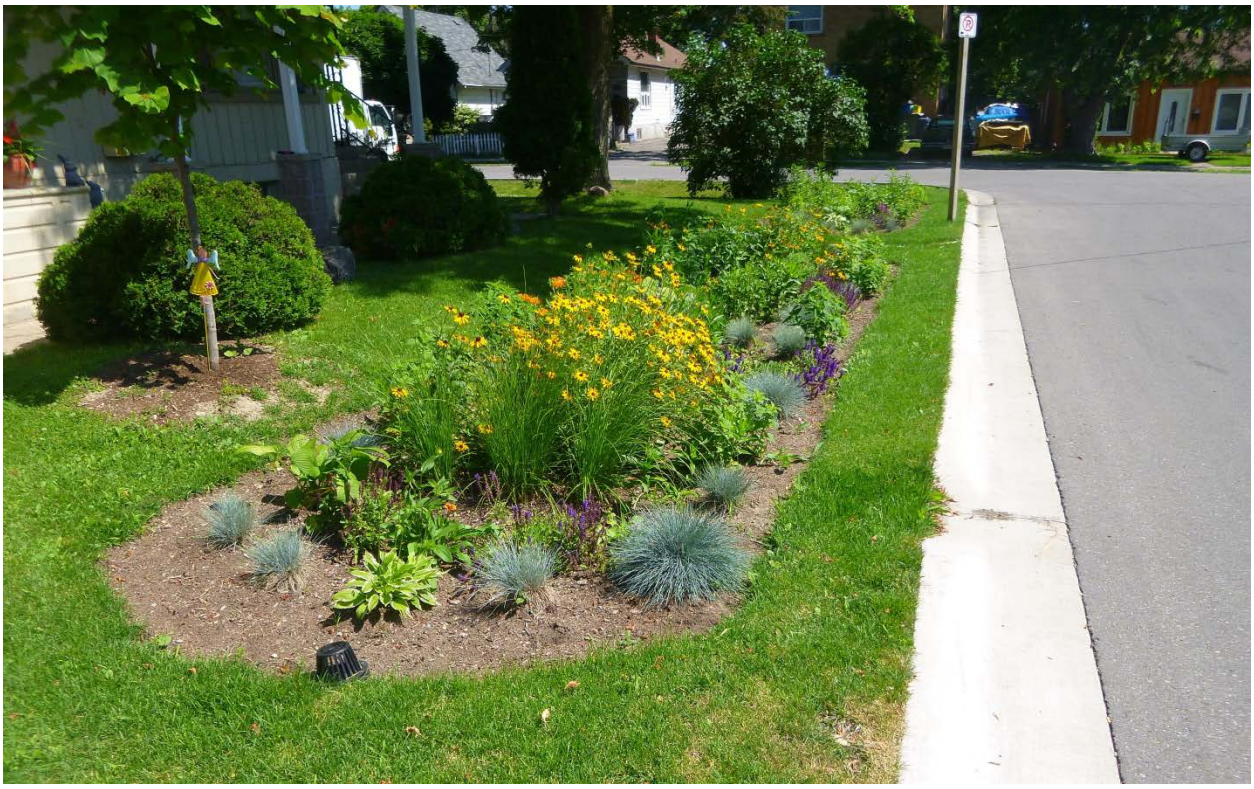
WORKSHOP DISCUSSION PAPER

Roads and Runoff:

Implementing Green Streets in the Greater Golden Horseshoe

March 1, 2015
Port Credit Ontario



Green Communities CANADA

CVC CREDIT VALLEY CONSERVATION

WELCOME TO a discussion paper prepared for participants in the Roads and Runoff workshop, 1 March 2016, in Port Credit, Ontario. The paper is being circulated as advance reading to "prime the pump" by providing background and introducing potential barriers and solutions for consideration.

Green streets, which manage road runoff in the right-of-way through filtration, infiltration or evapotranspiration have many benefits, but require a significant change of practice and culture. The paper invites participants to think about the drivers for managing road runoff in public rights-of-way and how to accelerate implementation of measures to reduce stormwater volumes and runoff pollution. At the workshop we will share our ideas in order to create a road map for moving forward. This road map will be shared with participants and key decision makers following the workshop. Our aim is that green streets will become business as usual in road construction and reconstruction in the Greater Golden Horseshoe Area and across the province. This will be done by addressing barriers and incentives to implementation at all stages – from planning, to design, to construction, to maintenance.

This paper has been prepared by Clara Blakelock and Clifford Maynes of Green Communities Canada. Please direct comments and questions to info@raincommunitysolutions.ca.

Roads and Runoff is a project of Green Communities Canada, in partnership with Credit Valley Conservation.

Thanks for financial support to the project from the Places to Grow Implementation Fund of the Ontario Ministry of Municipal Affairs and Housing.

QUESTION TO CONSIDER FOR DISCUSSION AT THE WORKSHOP:

From your perspective, what are the top three barriers to the implementation of green streets in your community? How can these be addressed?

Contents

Introduction

Urbanization, climate change, and green infrastructure

URBAN AREAS are covered in hard surfaces – buildings, parking lots, driveways, and roads. When a forest or meadow becomes a city, the increase in impervious area interrupts the water cycle and greatly increases runoff volumes and peaks. Climate change further heightens volumes and peaks by increasing the incidence of extreme wet weather events.

Impacts include urban and riverine flooding, erosion, altered water balance (which impacts stream base flows) and loss of groundwater recharge. Increased runoff and loss of natural filtration -- and in some locations combined sewer overflows -- results in pollution, which can affect aquatic ecosystems, recreational uses, and source water for drinking.

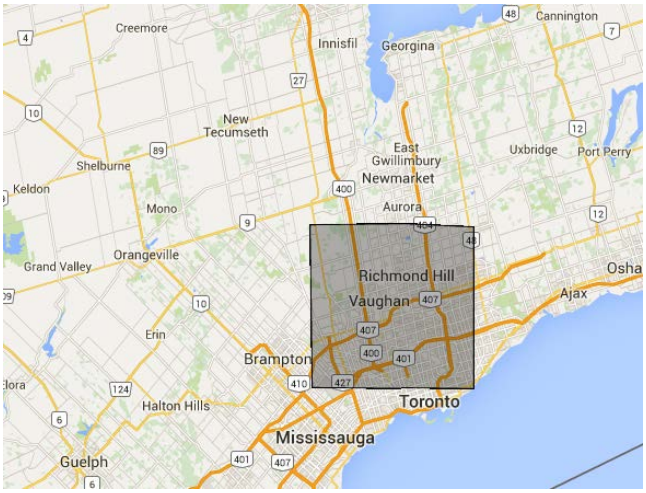
Part of the answer to the problem of urbanization and climate change is to restore and mimic the natural water cycle through a combination of natural and constructed features known variously as green infrastructure (GI), low impact development (LID), stormwater innovations, etc.[i] Measures to manage rain where it falls and reduce stormwater volumes can include rain gardens, bioswales, permeable pavement, urban trees, and infiltration trenches.[ii]

Many US cities are investing hundreds of millions of dollars or more in green infrastructure to manage stormwater, and adopting policies and programs to mobilize private investments. Canadian cities are also beginning to use this approach.

Roads and runoff – problems and solutions

There are nearly 200,000 km of two-lane equivalent roads (paved and unpaved) in Ontario,[iii] creating over 1,100 km^2 of impervious surface.[iv]

Twenty-five millimeters of rainfall across the entire road network generates over 25 billion litres of stormwater runoff, and millions of kilograms of pollution. Roads have been found to produce as much as 80 per cent of stormwater pollutant loading in urban areas.[v]



1,100 km^2 covers an area larger than the entire City of Toronto.

Road-related pollution found in stormwater includes oil, grease, metals and chemicals from vehicles, road salt, and sediment. In summer months, thermal pollution can be a major concern in areas with sensitive species in receiving streams.

In urban areas, rain is generally removed from roads through storm drains and underground pipes, and discharge directly to waterbodies. Alternatively, in more recently developed areas, rain is drained to stormwater ponds, where it is held before being discharged, and some level of treatment is provided. Roadside ditches designed for conveyance perform this function in older and more rural areas.

However, there is a growing understanding that these methods do not adequately treat the pollution from roads, nor do they restore the natural water balance, maintain groundwater recharge or pre-development stream flows. Many of these systems are aging and were not designed to accommodate increased volumes due to

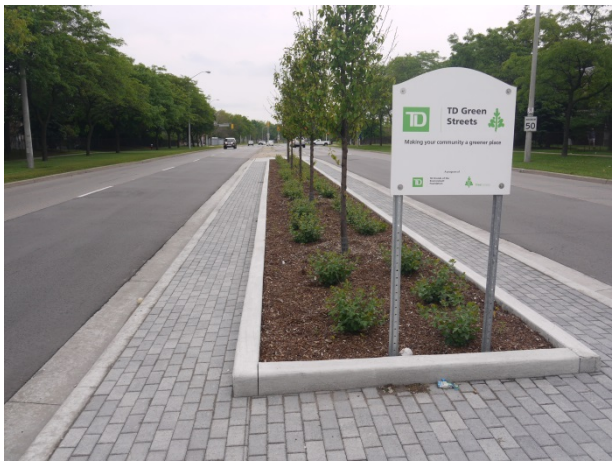
urbanization and climate change, resulting in flooding that can cause damage to roads themselves, homes, businesses and nearby infrastructure. Even up to date systems using conventional pipes and ponds cannot meet targets for quantity and quality control, and thermal pollution from stormwater ponds can shock receiving streams. Hence the emphasis on innovative green infrastructure that manages rain where it falls.

Part of the solution is to implement green infrastructure in rights-of-way. This makes sense given the contribution of roads to runoff and pollutant loadings, and the opportunity to implement green infrastructure on public property during road construction and reconstruction.

Green Streets

The "green streets" approach has been used with great success in pilot projects, and on a wider scale across the urban landscape in some U.S. cities. These streets either replace or supplement traditional grey stormwater infrastructure with green infrastructure installed in the road rights-of-way – practices such as permeable paving, bioretention, urban trees or infiltration galleries. Green streets can be implemented in new development, or as part of retrofits to upgrade stormwater systems or roads. See video for some examples of green streets installations.[vi]

Green streets can provide volume reductions and quality improvements in high density urban areas where land is scarce and very expensive. Because of the incorporation of trees and other vegetation, co-benefits include carbon sequestration, improved air quality, and urban heat island mitigation.



Silva cells help to green Central Parkway in Mississauga, Ontario.
Source: Credit Valley Conservation

Green streets can also support active transportation and complete streets.[vii] For example, bump outs which narrow roadways at pedestrian crossings to slow traffic flow can also function as bioretention systems. Healthy, mature street trees provide shade to sidewalks, making walking more pleasant for pedestrians. Sidewalk planters also create more walk-friendly environments.

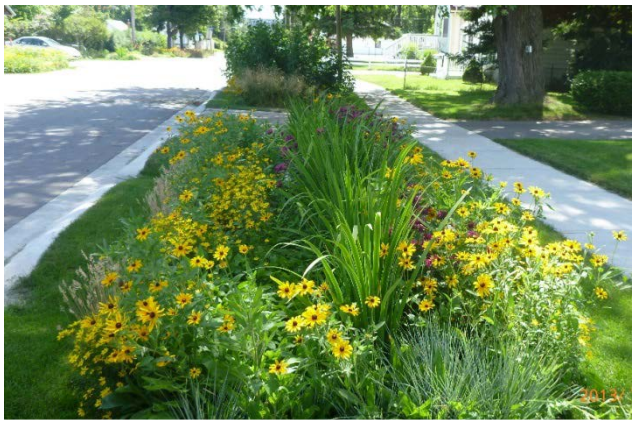
A study conducted in Burnsville, Minnesota on rain gardens in residential rights of way demonstrates how effective these techniques can be. Monitoring of two adjacent neighbourhoods, one of which had 17 rain gardens installed in rights-of-way, showed the rain gardens were able to reduce runoff volumes by 90% compared to the control neighbourhood.

Burnsville Stormwater Retrofit Study, 2006
http://www.ci.burnsville.mn.us/DocumentCenter/Home/View/449

Green streets project examples

At the workshop on 1 March, speakers will provide first-hand accounts of how some green streets projects came to be built in the Greater Golden Horseshoe Area, and how they have been performing. Below are a few other examples.

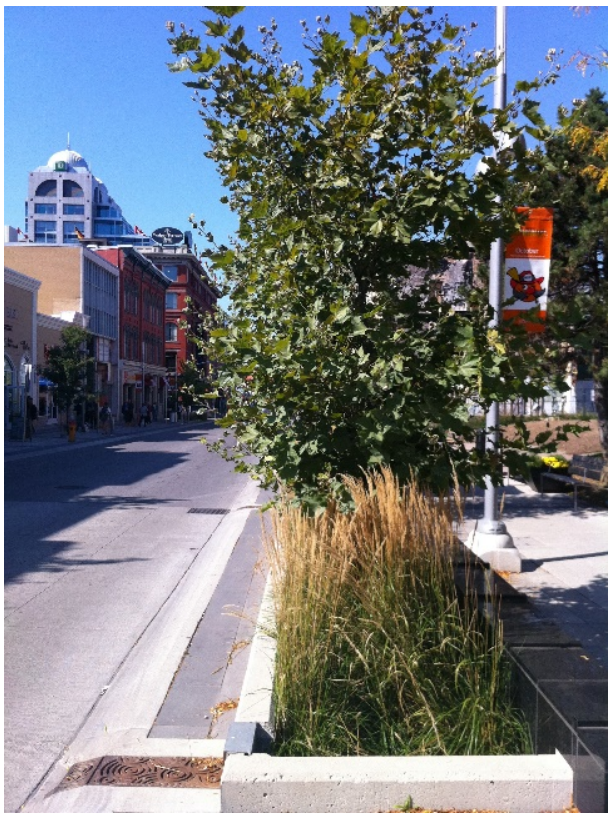
The Lakeview[viii] project developed by the City of Mississauga and Credit Valley Conservation took place in a residential neighbourhood draining directly to Lake Ontario, where stormwater management consisted of deteriorating ditches and culverts. Bioretention and permeable paving were installed in the rights-of-way of 285 m of roadway. Lakeview is considered Canada's first green street, and a number of lessons were learned about engaging residential property owners adjacent to the projects, construction best practices, and landscaping.



Close up of a bioswale in the Lakeview neighbourhood of Mississauga.
Source: Credit Valley Conservation

In the Elm Drive LID retrofit,[ix] also developed by City of Mississauga and Credit Valley Conservation, six bioretention planters were installed on Peel District School Board property adjacent to the right-of-way, while permeable pavers were installed in the municipal right-of-way. The system was designed to take runoff from the road, filter it through the permeable pavement, and channel it into the bioretention planters.

The Elm Drive project has been monitored since its installation in 2011, and it has been found to virtually eliminate runoff and pollution for 90 per cent of annual rainfall events. It has even performed well in extreme weather events that go well beyond its design specifications. During the 8 July 2013 storm in Mississauga, in which 105mm of rainfall fell over five hours, the installation reduced volumes by 30 per cent and peak flows by 60 per cent. Peak flows were delayed by 20 minutes. See the case study and full monitoring report.[x]



Bioretention planters on King Street in Kitchener.
Source:http://www.creditvalleyca.ca/green_project/marker/king-street-bioretention-planters/

The City of Kitchener developed the King Street project with the primary goal of creating a more pedestrian-friendly downtown.[xi] The design, which won the International Community Places Award in 2010, also incorporated several green street elements, including bioretention planters that collect road runoff, and 120 street trees. Because Kitchener relies on groundwater for its drinking

water, the bioretention units were designed to be shut off during winter months to reduce the risk of contaminating drinking water supplies with road salt.

Green streets at a community scale

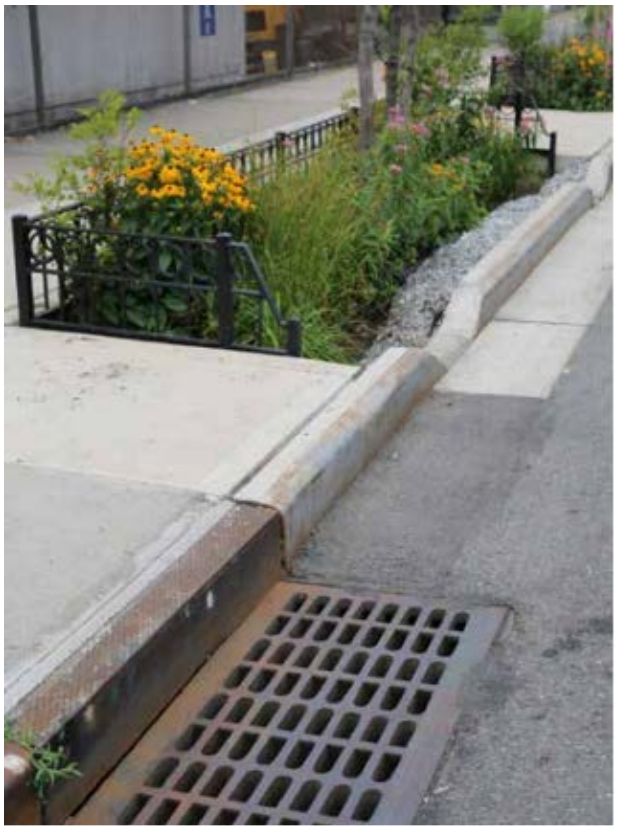
Cities in both Canada and the U.S. are now overcoming the barriers faced by road right-of-way green infrastructure projects and proceeding to implement projects at a community-wide scale.

Mississauga City Council passed a resolution in 2014 to consider the use of low impact development for stormwater management in every road reconstruction project.[xii]

The City of Toronto is currently developing Green Streets Technical Guidelines for the implementation of green streets during road construction and reconstruction, to comply with Toronto's Green Standard. The Green Streets guidelines will be designed to work in conjunction with the Complete Streets guidelines, also in development. Sheila Boudreau of the City of Toronto will provide further details on the status of this project at the workshop on 1 March.

In the U.S., several cities are already implementing green streets at a broad scale. New York City's Green Infrastructure Plan, released in 2010, includes a standardized approach to green infrastructure in rights-of-way. The City is tendering area-wide contracts to achieve economies of scale. Each contract consists of approximately 100-200 bioswales over ten green streets. As of the end of 2014, 866 right-of-way projects were under construction.[xiii]

Philadelphia's Green City, Clean Waters program is designed to eliminate combined sewer overflows through the use of green infrastructure. Streets and sidewalks make up 38% of the impervious cover in the combined sewer area of the city.[xiv] In 2014, Philadelphia Water released a Green Streets Design Manual that works in conjunction with the Philadelphia Complete Streets Design Handbook, published by the Office of Transportation and Utilities. Over 200 green streets projects have been constructed or are in design in Philadelphia.[xv]



Right of way bioswale in Brooklyn, NYC.
Source:http://www.nyc.gov/html/dep/pdf/green_infrastructure/gi_annual_report_2015.pdf

Other cities with extensive green streets programs include Washington D.C.[xvi] (which will be highlighted at our workshop on 1 March), Portland, Oregon,[xvii] Milwaukee,[xviii] and Seattle.[xix]

The Ontario Policy Context

ALTHOUGH IN theory, going back at least as far as the 2003 Stormwater Management Planning and Design Manual,[xx] source controls (green infrastructure/LID) were encouraged in Ontario, in practice industry standards and approvals have favoured conventional pipes and ponds. In recent years, the Ontario government has acknowledged that conventional methods of managing stormwater are unable, by themselves, to achieve

water quality and quantity objectives and that a change in practice is needed.[xxi]

Drivers for change in stormwater management

Water quality and quantity

- Canada-Ontario Agreement on Great Lakes Water Quality and Ecosystem Health
- Great Lakes Strategy and Great Lakes Protection Act[xxii]
- Water Opportunities and Water Conservation Act[xxiii]
- source water protection plans[xxiv]

Climate change

- Ontario climate change strategy released in 2015. A detailed action plan is expected in 2016.[xxv]
- Policy review of municipal stormwater management in light of climate change[xxvi]

Improved land use

- 2014 Provincial Policy Statement[xxvii]
- Growth Plan for the Greater Golden Horseshoe[xxviii]
- co-ordinated land use planning review[xxix]

The Growth Plan for the Greater Golden Horseshoe (Places to Grow) states that "municipalities are encouraged to implement and support innovative stormwater management actions as part of *redevelopment* and *intensification*." A 2015 coordinated review of the Growth Plan and other related plans emphasizes the need for increased green infrastructure to protect water resources and adapt to climate change.

Stormwater runoff is a major source of pollution to surface waters, in the Great Lakes Basin and beyond. Urbanization also impacts water quantity – reducing the water that is absorbed into groundwater aquifers and increasing surface flows to streams.

"…natural systems provide low-cost adaptation solutions. For example, wetlands can provide effective storm water management services and help mitigate the impacts of extreme weather on infrastructure such as storm sewers."

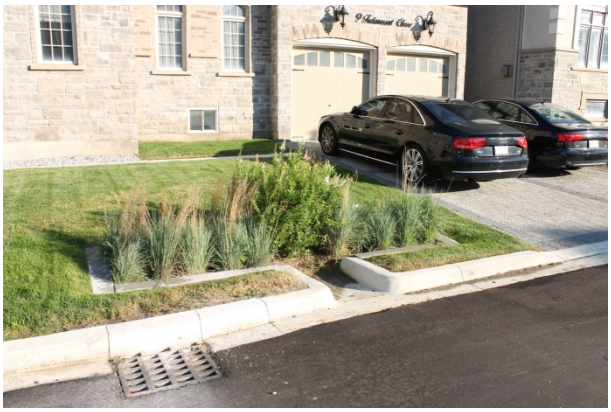
Ontario Climate Change Strategy, 2015

Despite increased policy support for green infrastructure/LID, progress in implementation has been slow. In a 2014 report,[xxx] the Environmental Commissioner of Ontario sharply criticized the Ministry of Environment and Climate Change (MOECC) and other ministries for inaction on implementing new approaches to stormwater management.

However, it appears that the tide is turning. In February 2015 MOECC released a strongly worded interpretation bulletin on stormwater management policy which stated: "the natural hydrologic cycle should be maintained to the greatest extent possible" by managing rain where it falls.[xxxi] In other words, source reduction is now the province's top priority for stormwater management, and green infrastructure may even be able to reduce the need for conventional

methods. This bulletin acknowledged that current approvals processes do not always support this innovative approach.

Work is now under way by MOECC to develop a Low Impact Development guidance manual, due for completion in 2016. The manual will outline the process and expectations for incorporating green stormwater infrastructure. Importantly, it will establish provincial targets for stormwater volume reduction. For example, many leading jurisdictions in the U.S. and Canada have adopted a target of 25 mm (1") or more for managing rain onsite, which means that the first 25 mm of runoff must be eliminated through onsite infiltration, evapotranspiration, and harvesting and reuse.



Bioswales and permeable pavement in front of new development homes in Brampton, Ontario.
Source: Credit Valley Conservation

The Ministry has stated that its LID guidance and volume reduction targets will apply across the landscape -- which presumably includes road development and re-development projects.

Barriers and Solutions

Despite all the benefits, demonstration projects, and policy support, green streets are still not business as usual for road construction and reconstruction in Ontario. Through discussions with stakeholders, we have identified several barriers that we believe contribute to the lack of uptake. We also suggest possible solutions where they can be identified. At the 1 March workshop we will expand upon these barriers and solutions with your input, and identify priorities for action.

Barriers

Lack of awareness
Municipal decision-makers and managers may not even consider the potential for integrating green stormwater infrastructure in rights-of-way, and resulting benefits.

Concern about performance
May include:
- o belief that soil conditions cannot support infiltration
- o lack of trust in ability of green stormwater infrastructure to manage runoff on a large scale
- o winter performance

Concern about costs
Many studies have shown that green infrastructure (or a grey-green combination) is cheaper than grey infrastructure alone.[xxxii] However, in initial stages, higher costs may actually occur in some cases. For example:
- o increased planning and design time for incorporating new technologies
- o lack of locally available materials
- o lack of local capacity for construction and maintenance

Concern about groundwater/ drinking water contamination.
Some communities are concerned about the risk to groundwater resources posed by infiltrating polluted stormwater.

Concern about maintenance.
Communities are concerned about perceived increase maintenance requirements for vegetation and planters to retain infiltration capacity.

Lack of capacity.
Capacity development of municipal staff, consultants, and contractors may be required at every stage:

- planning
- design
- construction
- maintenance

Lack of champions.
Green streets may lack a champion on staff who is able to convince others.

Local regulations and standards.
Municipalities may have established reconstruction that exclude or even discourage infiltrating runoff. Examples include:

- minimum road width and parking requirements that reduce space for green infrastructure
- grey infrastructure requirements that do not allow for reduced sizing with the inclusion of green infrastructure

Design challenges.
These may include:

- limited space
- tight soils
- other infrastructure in the rights-of-way
- other uses of rights-of-way

Communication/coordination between different departments.
Departments within a municipality that need to be involved in a green infrastructure right-of-way project include:

- planning
- engineering
- parks/landscaping
- public works
- stormwater

These departments often operate in completely different spheres, and may not be used to coordinating budgets, construction, maintenance etc. between them.

Responsibilities divided according to level of government.
Upper tier (regional) governments are responsible for regional roads and stormwater on regional properties in some areas, while lower tier (municipal) governments are responsible for municipal roads and stormwater. Coordination between these levels of government can be challenging.

Lack of standardized decision-making, approval and review processes.
This can include:

- Lack of direction and strategic planning from high level decision makers
- Lack of design criteria, standards and specification
- No standard review processes

Solutions

Promotion.
Hold conferences, workshops. Create communities of practice for knowledge-sharing with provincial/federal support, multi-sectoral collaboration. Educate key stakeholders to overcome common myths.[xxxiii]

Research and documentation.
Compile and share data about the effectiveness of green streets, construction and maintenance costs, and managing runoff for ground and surface water protection.[xxxiv]

Training and guidance.
Provide information resources, technical guidance, and formalized training for planners, engineers, approvals staff, construction staff and maintenance staff.[xxxv]

Provincial regulation.
Adopt provincial requirements/ targets for onsite stormwater infiltration in all developments/ redevelopments, including roads. Ensure that standards do not require superfluous grey infrastructure – some of the biggest cost savings of green infrastructure come from reduced need for underground pipes and reduced sizing of ponds.

Local regulations and standards.
Review the local policy and approvals framework to ensure alignment with green streets. See the USEPA "water quality scorecard" [xxxvi] as a model. Do we need a similar guide for Ontario, including a section addressing green streets?

Market development.
Once there is a market for LID/green infrastructure, costs have been shown to lower dramatically (Chicago saw the cost of permeable concrete go down by 2/3 in six months once they started installing it in all alleyway retrofits).[xxxvii] So committing to widespread implementation of green streets is one way to lower costs.

Systematic approaches
Make infiltration in rights-of-way normal by developing standards and guidelines for evaluating options. See Grey to Green Road Retrofits guide for more detail.[xxxviii] New York City's 2014 green infrastructure annual report[xxxix] contains an overview of their strategy for coordinated implementation in rights-of-way.

Diverse project teams
Successful right-of-way projects include project teams with representatives from all the relevant departments from the beginning so that issues can be worked out from the start.

Integrated water management
A "one water" approach which considers stormwater, drinking water and waste water as part of one system at a watershed scale can help to break down barriers between departments and levels of government.

Question to consider before the workshop

There will be time dedicated during the workshop to coming up with solutions. However, because time is limited, we hope you will take some time in advance of the workshop to gather your thoughts on the following question so that discussions will be as productive as possible.

From your perspective, what are the top three barriers to the implementation of green streets in your community? How can these be addressed?

About Green Communities Canada

Green Communities Canada, founded in 1995, is a national organization that works with its member organizations and partners to implement practical community solutions for environment, health, infrastructure, and economy. We deliver RAIN Community Solutions and related programs like Depave Paradise to help implement green stormwater infrastructure.

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About Credit Valley Conservation

Credit Valley Conservation (CVC) is a leader in green technologies and has worked in collaboration with over 30 partners (including member municipalities, development community, local businesses, residents, Conservation Authorities and Ministries) to implement innovative green infrastructure practices like bioretention within municipal right of ways to manage stormwater runoff and improve the quality of water that enters receiving waterways

[i] Note – green infrastructure can refer to other services provided by natural systems outside of stormwater services. For the purposes of this paper, green infrastructure (GI) and green stormwater infrastructure (GSI) will be used interchangeably. Other commonly used terms include Low Impact Development (LID), stormwater innovations, source controls, best management practices, sustainable urban drainage systems and water-sensitive urban design.

[ii] Green infrastructure also includes wetlands and other natural systems as well as green roofs and rainwater harvesting. However, these are not applicable to road rights-of-way. For more information on types of green infrastructure in road rights-of-way, see Grey to Green Road Retrofits: Optimizing Your Infrastructure Assets through Low Impact Development, Credit Valley Conservation, p 4. http://www.creditvalleyca.ca/wp-content/uploads/2014/08/Grey-to-Green-Road-ROW-Retrofits-Complete_1.pdf

[iii] Statistics Canada, 2003. http://www.statcan.gc.ca/pub/16-002-x/2009001/tbl/transpo/tbl001-eng.htm. Note that this figure does not include additional impervious surfaces in the form of parking lots, sidewalks, buildings, etc.

[iv] This assumes (conservatively) a two-lane road width of 6m.

[v] Grey to Green Road Retrofits: Optimizing Your Infrastructure Assets through Low Impact Development, Credit Valley Conservation, p 2. http://www.creditvalleyca.ca/wp-content/uploads/2014/08/Grey-to-Green-Road-ROW-Retrofits-Complete_1.pdf

[vi] Video: Healing roadways in the Great Lakes with green infrastructure. http://www.modeldmedia.com/features/great-lakes-green-infrastructure-video-122215.aspx

[vii] Complete streets refer to streets designed for all ages, abilities, and modes of travel. See Complete Streets for Canada. http://completestreetsforcanada.ca/

[viii] Lakeview Neighbourhood Case Study. Credit Valley Conservation. http://www.creditvalleyca.ca/wp-content/uploads/2014/04/Lakeview-Case-Study_Apr_04_2014_FINAL1.pdf

[ix] Elm Drive Case Study. Credit Valley Conservation. http://www.creditvalleyca.ca/wp-content/uploads/2013/08/CVC-Case-Study-Elm-Drive_Aug20131.pdf

[x] Credit Valley Conservation. Elm Drive: Low Impact Development infrastructure performance and risk assessment report (2015). http://www.creditvalleyca.ca/wp-content/uploads/2015/04/ElmReport_01042015-web.pdf

[xi] The New King Street. https://www.kitchener.ca/en/businessinkitchener/KingStreetMasterPlan.asp

[xii] City of Mississauga (2014). *Resolution for LID*. http://www.peelregion.ca/council/agendas/pdf/rc-20140327/communication-pw-f2.pdf

[xiii] NYC Green infrastructure plan and annual reports. http://www.nyc.gov/html/dep/html/stormwater/nyc_green_infrastructure_plan.shtml

[xiv] Philadelphia Water. *Green streets program*.

[xv] See Philadelphia Water Green Streets program http://www.phillywatersheds.org/what_were_doing/green_infrastructure/programs/green_streets and complete streets handbook http://www.philadelphiastreets.com/images/uploads/resource_library/cs-handbook.pdf

[xvi] District Department of Transportation. *Green infrastructure*. http://ddot.dc.gov/GreenInfrastructure

[xvii] City of Portland. *Green Streets*. https://www.portlandoregon.gov/bes/44407

[xviii] City of Milwaukee (2013). *Green streets stormwater management plan*. http://city.milwaukee.gov/ImageLibrary/Groups/cityGreenTeam/documents/2013/Green_Streets_Stormwater_Manag.pdf

[xix] City of Seattle. *Streetscape Design Guidelines*. http://www.seattle.gov/transportation/rowmanual/manual/6_2.asp

[xx] Stormwater management planning and design manual. http://www.ontario.ca/document/stormwater-management-planning-and-design-manual

[xxi] MOECC Interpretation bulletin re stormwater management (2015). http://www.raincommunitysolutions.ca/wp-content/uploads/2015/07/MOECC-interpretation-bulletin-re-stormwater-management.pdf

[xxii] See Canada Ontario Agreement on Great Lakes Water Quality, http://ec.gc.ca/lcpe-cepa/default.asp?lang=En&n=E9A42FF1-1 Great Lakes Strategy, http://www.ontario.ca/document/ontarios-great-lakes-strategy and Great Lakes Protection Act

http://ontla.on.ca/web/bills/bills_detail.do?locale=en&Intranet=&BillID=3115

[xxiii] Water Opportunities and Water Conservation Act (2010). http://www.ontario.ca/laws/statute/s10019

[xxiv] See for example, Greater Sudbury Source Protection Plan, p 38. https://www.greatersudbury.ca/sudburyen/assets/File/Greater_Sudbury_Source_Protection_Area_Approved_SPP_Sept_19.pdf and Source Protection Plan for the Niagara Peninsula Source Protection Area, p 32 http://www.sourceprotection-niagara.ca/wp-content/uploads/2015/12/1.0-SPP-text-MOE-Approved-131216R.pdf

[xxv] http://www.ontario.ca/page/climate-change

[xxvi] MOE (2011). *Policy review of municipal stormwater management in light of climate change.* http://www.ontario.ca/document/policy-review-municipal-stormwater-management-light-climate-change-summary-report

[xxvii] Provincial Policy Statement, 2014, http://www.mah.gov.on.ca/Page10679.aspx. See in particular Policy 1.6.6.7. Interestingly, Policy 2.2.1 requires that "planning authorities shall protect, improve or restore the quality and quantity of water by … ensuring stormwater management practices minimize stormwater volumes and contaminant loads, and maintain or increase the extent of vegetative and pervious surfaces." Since virtually all development reduces vegetative and pervious surfaces, this policy would appear to ban development in the province of Ontario.

[xxviii] Ontario Ministry of Infrastructure (2006). Growth plan for the Greater Golden Horseshoe. https://www.placestogrow.ca/content/ggh/2013-06-10-Growth-Plan-for-the-GGH-EN.pdf

[xxix] Crombie, D. (2015). *Planning for health, prosperity and growth in the Greater Golden Horseshoe: 2015-2041*. http://www.mah.gov.on.ca/Page10882.aspx

[xxx] Environmental Commissioner of Ontario (2014). *Sink, swim or tread water? Adapting infrastructure to extreme weather events.* http://eco.on.ca/wp-content/uploads/2015/03/2014-GHG-Sink-Swim.pdf

[xxxi] MOECC Interpretation bulletin re stormwater management (2015). http://www.raincommunitysolutions.ca/wp-content/uploads/2015/07/MOECC-interpretation-bulletin-re-stormwater-management.pdf

[xxxii] See several studies cited on the USEPA Green infrastructure cost-benefit resources webpage. http://www.epa.gov/green-infrastructure/green-infrastructure-cost-benefit-resources

[xxxiii] See Credit Valley Conservation. *Common perceived barriers to LID and how to overcome them.* http://www.creditvalleyca.ca/wp-content/uploads/2014/08/ROAD_RETROFITS_APPENDIX_E.pdf

[xxxiv] Research by the Sustainable Technologies Evaluation Program shows infiltration in tight soils is possible if measures are well-designed. While there may be specific sites where infiltration is not possible, it is not likely to be widespread across an entire urban area. See Young, D. (2015). *Go Deep – making infiltration work in tight soils.* *http://www.sustainabletechnologies.ca/wp/wp-content/uploads/2015/02/Young_2015_Go-Deep-SW-infiltration-on-tight-soils.pdf* There are also strategies available for pollution prevention and mitigating risks to groundwater –keeping in mind that pollution currently flows into surface water. BC Ministry of Environment (2014). *Underground stormwater infiltration: best practices for the protection of groundwater in British Columbia.* http://www.env.gov.bc.ca/wsd/plan_protect_sustain/groundwater/library/underground_stormwater_infiltration-2014.pdf

[xxxv] Some resources have already been developed. See Low Impact Development Stormwater Management Planning and Design Guide (2010). http://sustainabletechnologies.ca/wp/wp-content/uploads/2013/01/LID-SWM-Guide-v1.0_2010_1_no-appendices.pdf . Training programs are available from CVC, TRCA and LSRCA. See https://thelivingcitycampus.com/workshops/professional-workshops

[xxxvi] Water Quality Scorecard. USEPA, 2009. http://www.epa.gov/sites/production/files/2014-04/documents/water-quality-scorecard.pdf

[xxxvii] Attarian, J. (2010). *Greener Alleys*. https://www.fhwa.dot.gov/publications/publicroads/10mayjun/05.cfm

[xxxviii] Credit Valley Conservation. *Grey to green road retrofits: optimizing your infrastructure assets through Low Impact Development.* http://www.creditvalleyca.ca/wp-content/uploads/2014/08/Grey-to-Green-Road-ROW-Retrofits-Complete_1.pdf

[xxxix] NYC Environmental protection (2015). *NYC green infrastructure 2014 annual report.* http://www.nyc.gov/html/dep/pdf/green_infrastructure/gi_annual_report_2015.pdf