Credit Valley Conservation

Stormwater Management Monitoring Strategy Report

Version 1.0 - October 2012

Credit Valley Conservation Technical Report

Stormwater Management
Monitoring Strategy Report

Credit Valley Conservation
1255 Derry Road West
Meadowvale ON L5N 6R4

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Comments on this document should be directed to:

Christine Zimmer, P.Eng., MSc (Eng)
Manager, Water Resources Protection and Restoration
Credit Valley Conservation
1255 Old Derry Road
Mississauga, Ontario, L5N 6R4

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1.0 INTRODUCTION

Section 1 provides an overview of the overall purpose of the report; how it fits into CVC's overall SWM initiatives and watershed monitoring programs. Section 1 also provides details on the overall layout of the report to provide the reader with chapter context for easy review.

1.1 Purpose of the Strategy Report

Particularly in urban areas, effective stormwater management (SWM) is vital for health and safety, and protection of property and watercourses. SWM practices have evolved significantly in the last thirty years. In the 1980s, managers focused solely on controlling the quantity of runoff. Today, SWM addresses multiple issues including stream morphology, the protection of aquatic and terrestrial habitat and the protection of groundwater. SWM approaches and technologies continue to evolve, with the historical emphasis on treatment at the end of pipe giving way to "treatment train" approaches in which stormwater is managed at source, during conveyance and at the end of pipe where it is discharged into receiving waters.

Municipalities, developers and landowners spend large amounts of money to design, build and operate SWM facilities and systems. But are these systems working as designed? How do they perform over time as they age? Are some SWM technologies better than others at removing pollutants? How are these technologies to be sized if a treatment train approach is used versus stand-alone technologies? Are our design standards sufficient to protect the environment?

The answers to these and other questions come from monitoring. Compliance monitoring can help us understand whether a SWM pond or a rain garden is working as designed and whether it meets minimum acceptable regulatory standards. Performance monitoring can tell us how well a green roof or an infiltration basin performs, relative to design objectives and targets. Adaptive monitoring can tell us if our SWM approach is effective and/or whether we need to enhance SWM facilities to better protect water quality or be more durable.

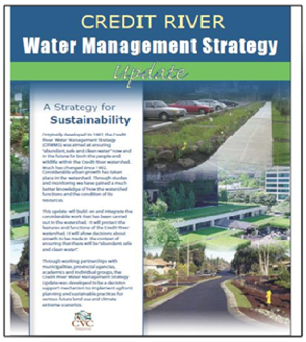
The *CVC SWM Monitoring Strategy Report* is intended to:

- highlight the importance of SWM monitoring in the design, construction, assumption, operation and maintenance of stormwater infrastructure to ensure long-term performance;

- provide an overview of how CVC's stormwater monitoring program fits within our watershed stakeholders priorities (Region of Peel and member municipalities, Ministry of Environment, Ministry of Natural Resources, Development Community);

- provide an overview of how CVC's stormwater monitoring program fits within CVC's existing stormwater initiatives and watershed monitoring programs;
- outline the main objectives for monitoring both conventional and innovative SWM methods;
- share SWM performance data to our stakeholders to build consensus on sizing SWM infrastructure to meet present and future conditions;
- provide future direction for the CVC SWM Monitoring Program;
- identify key issues and opportunities relating to monitoring SWM facilities and systems; and
- provide options for next steps to improve the monitoring of SWM facilities and systems in the Credit River watershed.

1.2 Background



Many studies have shown that, despite the use of conventional end-of-pipe SWM facilities, environment health continues to decline as urbanization increases in a watershed. This takes place despite widespread compliance with provincial and conservation authority requirements for SWM planning and design of facilities. As noted in CVC's 2007 Credit River Water Management Strategy Update (CRWMS Update):

> Conventional (end of pipe) stormwater management, which focuses on controlling peak flow rate and the concentration of suspended solids, has failed to address the widespread and cumulative hydrologic modifications in watershed that increase the volume of stormwater, increase the runoff rate, and cause excessive erosion and degradation of stream channels. Conventional stormwater management also fails to adequately treat other pollutants of concern, such as nutrients, pathogens, metals and thermal loadings.

Figure 1 Conventional SWM pond (left) and a constructed wetland (right)

To address some of the shortcomings of conventional SWM approaches, municipalities have begun to explore the use of Low Impact Development (LID) approaches, which are used to mimic pre-development hydrology through the processes of infiltration, evapotranspiration, rain harvesting, infiltration and detention of stormwater. LID practices include such technologies as green roofs, rainwater harvesting, downspout disconnection, permeable pavement, perforated pipe systems and infiltration chambers.

Figure 3 Two LID practices – bioretention cell (left) and engineered swale

All SWM systems − whether conventional or low impact development − need to be monitored to verify that the system as designed, approved, constructed and maintained complies with regulatory requirements. This local scale monitoring information can also be used to determine how SWM facilities − whether conventional or low impact development can be operated to improve water quality, meet hydrologic goals, optimize maintenance programs and provide ancillary benefits (i.e. reduce urban heat island or improve aesthetics). For example, the Lake Simcoe Regional Conservation Area report, Stormwater Pond Maintenance and Anoxic Conditions Investigation, is a great example of a monitoring report which demonstrates the performance of SWM ponds over time if not maintained (LSRCA, 2011). In addition, regional or watershed-scale monitoring provides invaluable information about the cumulative impacts of SWM infrastructure, which direct and inform criteria for SWM guidelines.

Who benefits from monitoring SWM facilities and systems?

- The development industry requires the feedback on field performance of SWM infrastructure to optimize capital cost and the amount of developable land.
- The construction industry requires the feedback to improve construction methodology and minimize the construction cost.
- The owner of a SWM facility or system requires information to ensure that the infrastructure has been constructed as per the design and performs as expected relative to the standards.
- The operating party needs performance monitoring results to plan for maintenance and the associated costs.
- Regulatory agencies seek performance data to evaluate the effectiveness of stormwater management technologies, to ensure the actual performance meets the set targets and objectives, to improve the existing design methodologies and to develop new tools and standards for the industry.

Consistent with other watershed studies, provincial guidance and literature review, a key finding in the CRWMS Update was that continued use of conventional SWM practices alone would lead to continued degradation of the watershed, jeopardizing the health of the Credit's world-class fishery and other resource values. To protect the health of the Credit River watershed, the updated water management strategy called for an immediate shift to more proactive and innovative SWM systems that include low impact development practices. Despite MOE support of these techniques since 1991 (Ontario Ministry of Environment and Energy, 1991), LID has a relatively short history in Ontario (more wide scale adoption has taken place in the US and Australia). There is limited local data on whether individual practices perform as designed and even less information on how individual practices perform in a treatment train (i.e. along with other practices). In some cases, there is limited data on how an LID practice performs in the Southern Ontario climate. The data that has been collected on the performance of LID practices is frequently not easily accessible, short term or not robust enough to draw conclusions.

During construction, the maintenance of a stormwater facility (such as a wet pond or an infiltration feature) is the responsibility of the developer. Once constructed, it becomes the responsibility of the property owner. In most cases, the facility becomes part of municipal infrastructure, and the municipality assumes the duty to operate, maintain and monitor it. MOE's *Stormwater Management Planning and Design Manual* (2003) provides some guidance on the inspection, monitoring and maintenance of SWM facilities. For example, it recommends that owners or managers prepare an annual maintenance report and use inspections to determine required maintenance activities. MOE can also incorporate monitoring, inspection and maintenance as conditions in MOE Environmental Compliance Approval (ECA). However, MOE has not developed monitoring standards for SWM facility approvals. Instead, conditions are determined on a site-by-site basis. Some municipalities have established regular stormwater monitoring programs to ensure that SWM facilities are functioning properly and to inform their maintenance schedule. The Town of Richmond Hill's SWM monitoring program, for example, has been in place for over 10 years. Through its monitoring program, the Town discovered that there were nearly 30 SWM facilities that needed major work. However, many of the municipalities across Ontario have not adopted such a comprehensive monitoring program (Drake and Goo, 2008).

Given limited resources and support for monitoring, many municipalities are unable to assess the ongoing performance of their SWM facilities to determine if they are in compliance, as it is very costly to monitor and maintain facilities. As they age, conventional SWM ponds fill up with sediment, which eventually has to be dredged and properly disposed of. If the sediment removed from a SWM pond is contaminated, it must be transported and disposed of at a certified landfill site or a hazardous waste facility. This can be very costly and many municipalities may not have sufficient funds set aside for this purpose. A few Ontario municipalities have dedicated funding sources for SWM maintenance, Halton Hills through development charges and Kitchener through SWM rates (CVC, 2008). A monitoring program can assist municipalities understand the scope of funding needed for pond maintenance over time.

The longevity of performance for stormwater treatment practices is dependent on maintenance actions. Maintenance involves significant resources (personnel, equipment, materials, sediment disposal expense, etc.). However, monitoring the performance of stormwater treatment facilities will make it easier to schedule appropriate maintenance to maintain optimal performance and extend the useable life of the practice.

1.3 Organization of the Report

The report is organized into eight sections and two appendices. A brief outline of each section is provided below:

Section 1 – Introduction: This section provides an introduction to the document and discusses the background to the issue.

Section 2 – CVC Water Monitoring Programs: This section provides an overview of existing monitoring programs and gives context on how site specific SWM monitoring fits into the CVC monitoring program scales. It also highlights stakeholder needs as it relates to SWM and monitoring.

Section 3 – Monitoring Conventional SWM Facilities: This section provides an outline of conventional SWM monitoring and an overview of monitoring goals

Section 4 – Monitoring Low Impact Development Practices: This section provides an outline of low impact development monitoring objectives and goals

Section 5 – Monitoring Pollution Prevention (P2): This section provides an overview of P2 monitoring objectives and goals.

Section 6 – Issues and Opportunities: This section summarizes key issues and opportunities relating to monitoring SWM facilities and systems.

Section 7 – Next Steps: This section outlines the recommended next steps relating to the CVC SWM Monitoring Strategy.

Section 8 – References: Provides key references to support the report.

Appendix A: Stakeholder initiatives and how CVC's monitoring strategy can assist in meeting SWM goals.

Appendix B provides an overview of 8 monitoring programs or studies.

Appendix C provides an in-depth look at the monitoring program being implemented at the Meadows in the Glen development.

2.0 CVC WATER MONITORING PROGRAMS

Section 2 provides context for CVC's SWM monitoring program both from an external funding perspective (how are we addressing funders needs and priorities) and internally (how does our monitoring program fit within CVC's broader SWM initiatives, and in-stream watershed monitoring programs).

2.1 How Are we meeting our Funders and External Stakeholder Needs

Since the release of the Credit River Water Management Strategy Update (CRWMSU) and signing of the Watershed Chart in 2007 CVC has been engaging stakeholders to determine what their needs and concerns are with respect to implementing the findings. As an outcome of these stakeholder consultations, CVC' initiated the SWM Monitoring Program in 2008 to build consensus among stakeholders with respect to critical SWM issues such as sizing SWM infrastructure to meet current and future conditions.

CVC's Monitoring Program plays a critical role in directing CVC SWM priorities and lays the foundation for the following SWM accomplishments:

- CVC/TRCA LID Design Guide- this guidance document was developed based on the need expressed by the development industry, municipalities for design, performance and maintenance information of LID measures in cold weather climates.
- CVC LID Landscape Guide- Given that LIDs are primarily on private property, stakeholders raised concerns regarding acceptance and maintenance of these practices by private landowners. Taking recent local market research, CVC developed a landscape guidance document to assist designers with generating support from private property owners. To build upon this document CVC is continually posting Case Studies on its website to provide further tools and lessons learned on overcoming maintenance concerns and private property acceptance
- CVC LID Construction Guide- given CVC's experience with LID sites, it became clear that Designers, Suppliers, Contractors, and Inspectors required tools and guidance on proper construction of LIDs. This document provides tools and lessons learned to properly LIDs.
- CVC SWM Criteria Document-to streamline approvals, and implement the findings of the CRWMSU, this document provides designers with development criteria.

These SWM Programs are intended to inform the Region of Peel Council Priorities for SWM in light of Climate Change; while also informing our municipal partners both within CVC's jurisdiction and beyond. Performance data for SWM techniques can support municipal initiatives such as Green Development Standards (Caledon, Mississauga, Halton Hills) and SWM Rates based on Impervious Cover (Kitchener and Waterloo) by providing insight into credits, rebates, etc.

From a provincial and federal perspective SWM performance data can help to inform approval agencies address such concerns as design features to prevent chlorides from entering wells (Environment Canada, MOE Source Protection), thermal loading (MNR's Redside Dace Requirements) and inherently support the Province of Ontario's Water Opportunities Act by providing information on innovative water technologies to position Ontario as a leader in Water; creating local green jobs while protecting our Great Lakes water quality).

Given the growth pressures projected within the Greater Toronto Area, how we build today will impact how we live tomorrow. In an effort to inform decision makers and the development community face the future challenges (climate change, aging infratrsucture, etc.) CVC's monitoring program is designed to address questions with respect to infrastructure sizing.

Stakeholder engagement on an annual basis is a critical component to the success of CVC's SWM Monitoring Program to ensure CVC is continuing to meet stakeholders' monitoring needs to advance the science, understanding and implementation of SWM measures to protect our waterways and the Great Lakes. For detailed **SWM monitoring objectives refer to Chapters 3 and 4 which incorporates CVC and stakeholder needs. A complete listing of CVC funder priorities (MOE, Municipalities, BUILD, and Region of Peel) and how CVC SWM monitoring are addressing them can be found in Appendix A.**

2.2 How does CVC's SWM fit within the broader Watershed Monitoring Program

The following section provides an overview of how CVC's SWM Monitoring Program fits within the context of CVC's broader watershed monitoring programs

2.3 Current Water Monitoring Programs

The following section provides a brief overview of CVC's monitoring programs.

2.3.1 <u>Watershed Monitoring Program</u>

Integrated Watershed Monitoring Program
CVC initiated the Integrated Watershed Monitoring Program (IWMP) in 1999 to track longer-term trends in watershed environmental health and to assess the impact of ongoing land use changes on aquatic and terrestrial conditions.

The IWMP focuses on a diverse range of monitoring parameters that act as indicators of ecosystem health. At a network of over 100 monitoring stations – see Figure 2.1 − CVC collects data on water quality, flows, fisheries, benthic organisms, water temperature, and other factors. Because the IWMP integrates expertise and data from disciplines such as meteorology, hydrogeology, hydrology, terrestrial ecology, fluvial geomorphology, water quality and biology, many aspects of the environment can be simultaneously analyzed. The IWMP's baseline values may not necessarily represent pristine conditions, but they do provide a starting point for comparisons of changes.

The information obtained through the IWMP is reported yearly in annual reports. Reports with more detail reports are completed every 5 and 10 years; these reports look at data trends and provide program review.

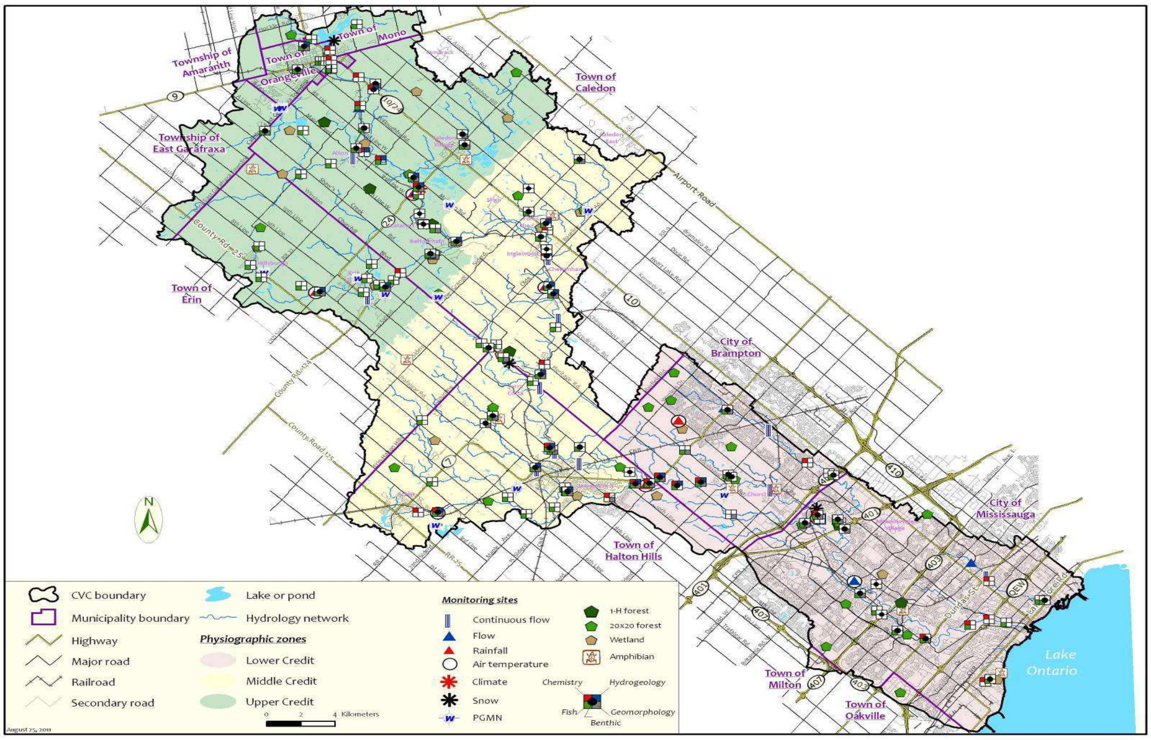


Figure 2 IWMP monitoring sites in 2011

Figure 3 CVC staff collecting water samples for the IWMP

Real-time Monitoring

The Real-time Monitoring Program involves continuous recording of water quality and quantity parameters at specific locations throughout the watershed. CVC uses the continuous data recorded at the real-time stations as an immediate water quality and quantity indicator to detect spills and flooding issues. Over the long-term, the data collected is analysed to detect changes in water quantity and quality that may be due to natural, anthropogenic or climate change-related stresses. Real-time monitoring allows CVC to better respond to spill and flooding events and track long-term changes in the watershed.

Figure 4 CVC Staff installing real-time monitoring station on the Credit River at Old Derry Road

2.3.2 **Urban Water Monitoring Programs**

Fletcher's Creek Monitoring
In 1998, the City of Mississauga initiated a three-year study to monitor hydrology, water quality, aquatic biology, aquatic habitat and geomorphology in Fletcher's Creek. The program was designed to assess the response of watercourses to urbanization. Upon completion, CVC continued the monitoring work in a downscaled version focusing on the hydrology and water quality, supplemented with data from the IWMP.

Brampton Effectiveness Monitoring
The Effectiveness Monitoring Strategy (EMS), was initiated in 2003 by CVC in conjunction with the City of Brampton, to determine the impacts of the City's proposed Urban Boundary Expansion for North West (NW) Brampton on watercourses. The objective of the EMS is to measure the current environmental conditions in discrete catchment areas (areas less than 150 ha in size) in order to assess the effectiveness of current land use planning controls and Best Management Practice (BMP) measures to provide guidance for future planning initiatives within NW Brampton.

In 2007, the EMS program expanded to include a proposed area of development known as the Credit Valley Secondary Plan (Blocks #1-6), an area of 12.2 km^2. Because of the lack information on groundwater in the area, the program expansion focused on improving the understanding of groundwater infiltration, groundwater movement and the effects of development on this subsurface system and the surrounding watercourses, Huttonville and Springbrook Creeks.

Figure 5 EMS monitoring site during high flows in 2003.

Impact Monitoring

The Impact Monitoring Program was established with an approval in funding from the Region of Peel in 2007. The purpose of the program is to establish cause and effect relationships in a deteriorated system by assessing the impacts of various land use and management practices on the health of the watershed. The program will ultimately be used as a model to provide input into proposed changes in land use and watershed management. By establishing a cause and effect relationship among these impacts, it will be possible to apply this information to other areas in the watershed where similar impacts or restorations activities are anticipated.

The current focus of the Impact Monitoring Program is in the Cooksville and Sheridan Creek watersheds, but the program can be moved to other areas of the Credit River watershed.

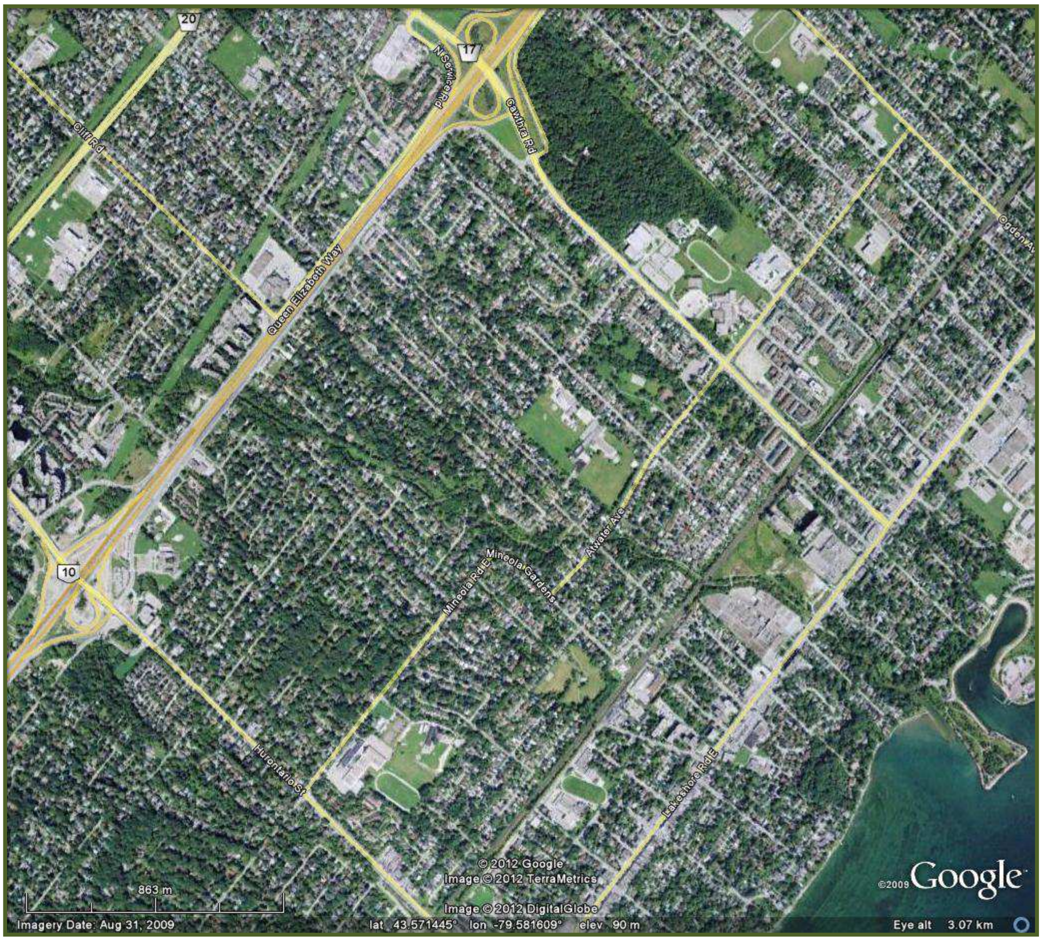


Figure 6 Image of urbanized Cooksville Creek in 2011 (Courtesy of Google Earth)

Credit River Tributaries Monitoring

The Credit River Tributaries Monitoring program was initiated in 2007. The purpose of the program is to establish baseline conditions prior to a significant land use change, (primarily agricultural to urban land use). These baseline conditions can then be used to compare environmental conditions during and after construction.

Figure 7 Image of Credit River Tributary Monitoring location in 2011 (Courtesy of Google Earth)

2.3.3 <u>SWM Monitoring Programs</u>

Site Level SWM Monitoring

The scale of CVC's current watershed monitoring programs are too large to successfully monitor individual SWM facilities or practices at the site level, or answer the issue of sizing infrastructure when applying a treatment train approach. Monitoring sites for watershed programs are spaced a considerable distance apart and are unable to assess the impacts of individual SWM facilities or practices on receiving streams as other influences may impact stream conditions. To address this gap, a more comprehensive Site Level SWM Monitoring program was created. The Site Level SWM Monitoring Program is intended to be adaptive in nature, implying that the programs will be continually reviewed and changes may be made to the sampling protocols, methods, and locations as information is gained and goals and objectives evolve (i.e. adding groundwater monitoring or water quality parameters to address new questions or legisliation). This program involves external partnership funding so parameters and frequency may influence protocols to address specific partner needs.

CVC's SWM monitoring programs can be separated into three types:

- **Compliance Monitoring:** This is monitoring designed to evaluate whether a management measure or facility is functioning as designed to meet minimum acceptable requirements (e.g., MOE Environmental Compliance Approval (ECA) for SWM facilities or municipal requirements prior to assumption of SWM facilities).

- **Performance Monitoring:** This refers to monitoring designed to evaluate how well a SWM facility or practice performs in comparison with a range of performance indicators or targets. Performance monitoring allows a comparison with other facilities, technologies, and/or development contexts. This information can inform both the LID Design and Landscape Guides.

- **Adaptive:** This is monitoring designed to evaluate how SWM practices can be improved, for example to improve water quality, meet hydrologic goals, last longer, require less maintenance, meet new challenges of climate change (i.e. plant selection for drought tolerance and high intensity short duration storms, and provide ancillary benefits). This information can inform both the LID Design, Landscape Guides and informs the SWM Criteria Document.

Municipalities have been designing, building and using conventional SWM practices for 30 years or so. There is a fairly long research history for conventional SWM practices such as wet ponds. Nevertheless, there are still many questions associated with these practices. As noted in section 1.1 of this report, SWM goals have evolved over the lasts 30 years. Are conventional SWM practices complying with new management criteria related to in-stream erosion, thermal pollution, and nutrient capture? Lake Simcoe Region Conservation Authority found that ponds were not meeting level 1 treatment after 7 years (LSRCA, 2011). As end-of-pipe systems age, what are the challenges associated with end of life rehabilitation (e.g., dredging of sediment)?

With respect to LID approaches, some of the practices (such as swales) have been used since the beginning of SWM, but not necessarily to meet the water resource objectives of today (water quality, water balance, and erosion control). While research institutions and water management agencies in North America, Europe, Australia, New Zealand and Japan have monitored the performance of various LID practices in various settings over the past two decades, the practices have only been widely used in Ontario in the last 5 years. The monitoring hurdles Ontario faces today with LID relate to implementation barriers and lifecycle issues. These are addressed in section 4.2 of this report. In the absence of monitoring, some municipalities in Ontario have been reluctant to give SWM credit to developers (i.e. reducing the size of or eliminating the permanent pool of a SWM pond) for incorporating LID practices into site design; but if credit is not given how will the pond perform- will it meet 80% TSS removal if solids are removed by upstream LIDs? Will the pond receive a 2,5 or 10 year storm? What will the pond look like if it only receives flows greater than a 5 year storm, will it be more susceptible to algae, mosquitos?.

Data and information obtained from the SWM Monitoring Program will be used by CVC, municipal, and provincial staff to help educate stakeholders on how to effectively manage stormwater and protect water resources from the impacts of stormwater and will help to update Guidance Documents such as the LID Design and Landscape Guides and SWM Criteria Document.

Figure 8 CVC Staff collecting monitoring data for the SWM Monitoring Program

SWM Monitoring to Inform SWM Guidelines

CVC in partnership with TRCA, Provincial agencies, member municipalities, GGH CAs and BILD have developed new SWM Criteria in light of CRWMSU and Humber Watershed Study Findings. How well SWM practices meet these criteria will need to be monitored with the intent to inform future revisions to the Criteria Document. For instance, **Existing monitoring of wetlands has shown that buffers in some cases are insufficient to protect wetland vegetation and species from the impacts of development. There exists a need to maintain water balances (surface and groundwater inflow and outflow and evapotranspiration) to a natural feature. New feature-based wetland water balances criteria is required for new developments within CVC and TRCA jurisdictions.** As part of this requirement CVC and its partners have laidout protocols for pre and post development monitoring. Information from these studies will help refine future protocols specified in the SWM Criteria Document and well also help inform future updates of the CVC/TRCA LID Design Guide (ie how can BMPs better distribute flows to wetlands to mimic pre-development).

3.0 MONITORING CONVENTIONAL SWM FACILITIES

This section provides an overview of conventional SWM practices and monitoring needs identified through stakeholder consultation.

3.1 Overview of Conventional SWM

Conventional SWM typically refers to systems with curb, gutter, and pipe conveyance and end-of-pipe control. End-of-pipe controls include artificial wetlands, dry ponds, infiltration basins, filters, and oil/grit separators, but by far the most commonly used end-of-pipe practice is the wet detention pond. Conventional SWM focuses on controlling the peak flow rate and erosive velocity of discharges and the concentration of suspended solids (e.g., a target of 80% removal of total suspected solids in wet ponds). Much of the development in the Credit River watershed has occurred in the last 30 years and these areas are currently serviced by conventional SWM. (In areas that were developed before 1980, there is little or no SWM).

To address these concerns, the new CVC SWM Criteria document provides guidance in the planning and design of SWM infrastructure consistent with the general directions provided by the CVC's CRWMSU for SWM. Within the context of current legislation, policies, and science relating to stormwater, management (SWM), this document provides additional guidance with respect to the Credit Valley Conservation Authority's (CVC's) specific watershed management strategies and programs consistent with MOE(2003) SWM Guidelines.

Figure 9 Floating Island Pilot Project on Pond 10 in Brampton (Source: CVC)

Monitoring for assumption and compliance: According to the MOE SWM Planning and Design Manual (MOE 2003), "*The consensus of opinion among practitioners is that monitoring for chemistry or biotic parameters cannot be justified for each individual facility because to have any scientific validity a large and costly sampling program is required. The approach generally used within the province is physical operation monitoring by the proponent to verify that the facility is operating as designed and detailed pilot site monitoring through research programs to evaluate effectiveness issues*". In Ontario, the Environmental Compliance Approval (ECA) is required by the Ministry of Environment for all SWM facilities and to issue an ECA, a detailed review of the plans are performed by the Ministry of the Environment to ensure the compliance with regulation. As a general condition to the Environmental Compliance Approval, the Ministry of Environment requires the owner of the facility to design, build, install, operate and maintain the works as described for review and upon which approval is granted

As part of CVC's commitment to sharing and distributing tools to help municipalities manage SWM, CVC approached various municipalities across Ontario to gather information on their requirements for SWM facility monitoring prior to and after the assumption of the facilities. Refer to Table 2. Consistent with the findings from Jennifer Drake and Yipping Goo (2008), there are no standard inspection or assumption procedures amongst municipalities and the quality of construction is quite variable. Most of the interviewed municipalities do not require developers to perform a mandatory cleanout of sediment prior to assumption. This may explain some of the findings in the Drake and Goo (2008) and LSRCA (2011) studies.

Long-term monitoring: The function of wet ponds steadily decreases as sediment is accumulated over time. To remain effective, ponds need to be regularly inspected and sediment must periodically be removed. However, a 2008 study by Drake and Guo at the University of Guelph found that the vast majority of Ontario municipalities are not monitoring their SWM ponds and lack adequate sustainable SWM funding commitment for costly pond refurbishment and the dredging of accumulated sediment.

Table 1 Survey of Municipal SWM Pond Assumption Procedures

Municipality	**SWM Monitoring Procedure**
City of Mississauga	Developers are required to perform a clean out unless the bathymetric survey indicates a minimal accumulation of sediment, in which case the developer will be required to provide a contribution for future maintenance work.
City of Brampton	Engineering consultants are required to provide a certificate to verify that the SWM pond has been built to design and complies with the Environmental Compliance Approval (ECA)l. No flow monitoring measurements are carried out by the consultant or the City before or after the pond is assumed.
Town of Halton Hills	Prior to assumption, developers are required to carry out a bathymetric survey. The Town also requires the developer to drain and clean out the pond if it is a newly approved pond. Currently, the Town does not perform any flow monitoring at the inlet and outlets, but this will be implemented as a requirement prior to the assumption of future ponds.
Town of Caledon	A consultant/engineer is required to carry out a bathymetric survey. The Town also requires certification of all the pond structures prior to assumption. Developers only monitor/maintain the SWM pond from construction to assumption. Currently there are no maintenance procedures in place but they may be implemented in light of the *Water Opportunities Act*. No flow monitoring procedures are carried out.
Town of Orangeville	A consultant/engineer is required to provide a table on the as built constructed plans that shows the design volume/discharge rate of the pond compared to the actual constructed volume/discharge rates for all storm events up to and including the 100-year event. The chart is prepared and reviewed by the Town prior to final acceptance of the pond design. The flow rate is not monitored. All calculations are done based on the design volumes and as-constructed information. Those numbers are checked against the actual design that was submitted and reviewed during the engineering submission process. As part of inspections for final acceptance, the Town and CVC inspect the pond for compliance. The Town and CVC must both be satisfied that the pond meets the design and its intent. The inspections include as-constructed information, calculation checks, and an in-field inspection of the structures and pond.

Monitoring Objectives for Conventional SWM

CVC's objectives for monitoring conventional systems fall within its mandate to monitor SWM for compliance, performance, and adaptation.

- **Compliance** monitoring focuses on assessing whether the facility is built as designed and whether it meets minimum acceptable regulatory requirements.

- **Performance** monitoring measures how well (or poorly) a SWM facility performs according to design objectives and targets. These studies are typically undertaken when little information is available regarding the effectiveness of a certain type of facility in a certain environmental context.

- **Adaptive** monitoring assesses how SWM practices can be enhanced to improve water quality, meet hydrologic goals, last longer, be maintained better, and provide ancillary benefits (for example to reduce urban heat island or improve aesthetics).

The Table 3.2 identifies eight CVC monitoring objectives for conventional SWM systems and categorizes them by type of monitoring. The objectives relate to both meeting stormwater criteria and improving the functionality of the facility in the southern Ontario context.

Table 3.3 provides a rationale for each of the eight monitoring goals, along with examples of monitoring studies that address the monitoring goal.

Please note these objectives will be refined with stakeholder input as our monitoring program and understanding of SWM performance evolves.

Table 2 Monitoring Objectives for Conventional SWM

Monitoring Objectives for Conventional SWM Management	Type of Monitoring		
	Compliance	Performance	Adaptive
1. Evaluate how SWM ponds perform with LID upstream. Can the wet pond component be reduced or eliminated by meeting the erosion and water quality objectives with LID?	X	X	
2. Evaluate whether conventional SWM systems are providing flood control, erosion control, water quality, recharge, and natural heritage protection as per the design standard.	X		
3. Evaluate thermal impacts and mitigation techniques for stormwater ponds (e.g. floating islands, cooling trench)	X	X	
4. Evaluate the use of dry detention areas for recreational uses; multiple use dry facilities can be implemented as retrofits in parks in areas pre-dating SWM, or make the implementation of LID in new developments more economical.			X
5. Evaluate nutrient removal and export from stormwater ponds.	X	X	
6. Evaluate the function of deeper ponds with respect to stratification, thermal, and oxygen gradients.	X	X	X
7. Evaluate impacts of length to width ratios on water quality and temperature.	X	X	X
8. Assess the decline in infiltration rates and the potential for groundwater contamination with the use of large centralized end-of-pipe infiltration basin systems.		X	
9. Assess the ongoing maintenance needs of existing SWM systems and evaluate 9. methods for monitoring compliance with maintenance agreements.	X		

Table 3 Additional Background on Conventional SWM Monitoring Goals

Monitoring Objective	Rationale for Monitoring Objective	Examples of Monitoring Studies
1. Evaluate how SWM ponds perform with LID upstream. Can the wet pond component be reduced or eliminated by meeting the erosion and water quality objectives with LID?	Installation of LID practices in a site may allow “downstream” wet ponds to be reduced in size. For developers, a reduction in the pond size or elimination of the wet component would allow for more land that is developable. An acceptable method for resizing stormwater ponds needs to be established in cases where LID practices are used upstream to treat runoff and reduce volumes. SWM approval agencies in the US have different methods for resizing ponds with upstream LID such as adjusting runoff coefficients or requiring continuous modeling, but an Ontario-specific method needs to be developed.	CVC has conducted a survey of US requirements; refer to CVC’s website for further information. This objective can be evaluated by either conducting a water balance on the pond with LID upstream or alternatively by monitoring the flows from the downstream outlet from an LID system. *See Appendix, Meadows in the Glen Monitoring Plan*
2. Evaluate whether conventional SWM systems are providing flood control, erosion control, water quality, recharge, and natural heritage protection as per the design standard.	Evaluation of whether a new SWM system complies with minimum regulatory requirements is the responsibility of the developer of the facility. The typical timeframe for demonstrating that requirements have been met ranges from 2 to 5 years following construction. Minimum requirements such as water quality may be considered to be met based on the presumptive approach that assumes that if the facility is constructed and maintained to the design standard then it meets the criteria. However, studies on wet ponds by CVC, TRCA, and LSRCA have found that actual water quality performance has fallen below the minimum standard.	Studies monitoring the hydraulic and water quality performance of a pond will require monitoring stations at the inlet and outlet of the pond. *See Appendix, Pond 10 Monitoring – SWM Pond, (LSRCA). 2011. Stormwater Pond Maintenance and Anoxic Conditions Investigation - Final Report and also Monitoring and Performance Assessment of a Highway Stormwater Quality Retention Pond – Rouge River, Toronto, Ontario on the STEP website*.
3. Evaluate thermal impacts and mitigation techniques for stormwater ponds (e.g., floating islands, cooling trench)	Section 4.4 of the MOE SWM Planning and Design Manual (MOE 2003) refers to the fact that the use of stormwater ponds can impair receiving stream habitat through heating of the discharge water. The temperature difference between the inlet and outlet flows of stormwater ponds in Ontario have been found in the range of 5^{o} - 7^{o} C (CVC Study Report: Thermal Impacts of Urbanization including Preventative and Mitigation Techniques).	At an existing SWM facility where vegetated islands were installed to mitigate thermal impacts of stormwater, monitoring examined variables of shape, size, percentage of pond surface, product, placement and plant species. *See Appendix A-6, Brampton Pond 10 Floating Island Study.* Cooling trenches are another pond outflow thermal mitigation practice. *See study of Pond H-3 cooling trench in Block 2 of Brampton.*

Monitoring Objective	Rationale for Monitoring Objective	Examples of Monitoring Studies
4. Evaluate the use of dry detention areas for recreational uses; multiple use dry facilities can be implemented as retrofits in parks in areas pre-dating SWM, or make the implementation of LID in new developments more economical.	The use of dry detention for other uses like playing fields can allow developers to get more buildable land in new development. Areas with development predating SWM and no space for new ponds, may have opportunities for dry detention retrofits in park and open space. This is important because if it is found that LID can meet water quality and erosion objectives, then the wet pond component can be eliminated. Parks and recreation departments will need to be satisfied that dry detention will not compromise park use if incorporated into parks.	These studies may evaluate the frequency and depth of flooding within the dual or multi-use facility by monitoring water levels in the outlet structure. Qualitative data from the feedback of property owners, users, and maintenance staff on the functionality of existing multi-use dry detention facilities may also be collected. Case studies are being collected by CVC as part of CVC's Showcasing Water Innovation (SWI) Funding Grant
5. Evaluate nutrient removal and export from stormwater ponds.	Nutrients are a major pollutant of concern for the Credit River and Lake Ontario and SWM ponds may be doing an inadequate job of capturing nutrients. Research from LSRCA has found some existing stormwater ponds that are exporting nutrients. Furthermore, nutrient loading in the developing headwaters subwatersheds is resulting in water quality that exceeds PWQOs and threatens high quality fisheries.	Studies monitoring the hydraulic and water quality performance of a pond will require monitoring stations at the inlet and outlet of the pond. *See (LSRCA). 2011. Stormwater Pond Maintenance and Anoxic Conditions Investigation - Final Report and also* *Monitoring and Performance Assessment of a Highway Stormwater Quality Retention Pond – Rouge River, Toronto, Ontario on the STEP website*.
6. Evaluate the function of deeper ponds with respect to stratification, thermal, and oxygen gradients.	A number of studies have demonstrated that thermal gradients can occur within SWM ponds. Outlet structures placed near the bottom of a pond have the potential to discharge cooler water than surface outlets. There are concerns that a deeper pond depth may lead to anoxia (oxygen depletion) near the bottom, which in turn may stimulate release of phosphorous or other substances from bottom sediments.	Studies that measure the temperature and oxygen levels of ponds at multiple depths would provide data on stratification of temperature and oxygen levels. An inlet/outlet comparison of ponds using a bottom draw outlet would also determine the viability of the design for cooling water while maintaining oxygen levels.
7. Evaluate impacts of length to width ratios and orientation of SWM ponds on water quality and temperature.	Length-to-width ratios in the design of stormwater ponds can play an important role in determining the shading potential. Current guidelines suggest using a minimum ratio of 5:1, however increasing this ratio (up to 10:1) may allow for more effective shade coverage. In addition, the direction or orientation of a pond can play a major role in increasing the shading ability of shoreline vegetation. The concept is to orient the pond to increase shading potential, thereby decreasing the amount of open water that can be affected by solar radiation.	A comparison study of existing stormwater ponds with varying orientations to the sun and length to width ratios can establish the impacts that those variables have on thermal impacts to stormwater. The sites should have established vegetation (minimum of 5 years old). Continuous measurements of temperature inflow and outflow would be required.

Monitoring Objective	Rationale for Monitoring Objective	Examples of Monitoring Studies
8. Assess the decline in infiltration rates and the potential for groundwater contamination with the use of centralized infiltration basin systems.	While included in the 2003 MOE SWM Design Manual, infiltration basins have rarely been used within the CVC watershed as most development has occurred over low infiltration soils. There has also been limited recharge and water balance requirements. As development increases in high infiltration zones over the Oak Ridges Moraine and recharge and water balance becomes mandatory, there is the potential for more frequent use of centralized infiltration basins.	To evaluate infiltration rate declines, infiltration tests can be performed within infiltration basins over a longitudinal time study. Monitoring of water quality in groundwater wells near infiltration basins will be necessary to evaluate groundwater contamination impacts.
9. Assess the ongoing maintenance needs of existing SWM systems and evaluate methods for monitoring compliance with maintenance agreements.	MOE Certificates of Approval permits may require ongoing maintenance of the stormwater practice. Municipalities and property owners often have inadequate funds for storwmater management operation and maintenance. For example, oil/grit separators filled to capacity with debris are a common occurrence. Monitoring is a critical component of maintenance and operations in order to establish needs and budget.	A survey on the state of existing SWM systems on public and private property will help to better define the problem. A letter reminding permit holders of their responsibility to maintain their SWM systems, then a follow-up survey could evaluate the effectiveness of the reminder approach.

4.0 MONITORING LOW IMPACT DEVELOPMENT PRACTICES

This section provides an overview of LID BMPs and monitoring needs for wide-scale adoption.

4.1 Overview of Low Impact Development

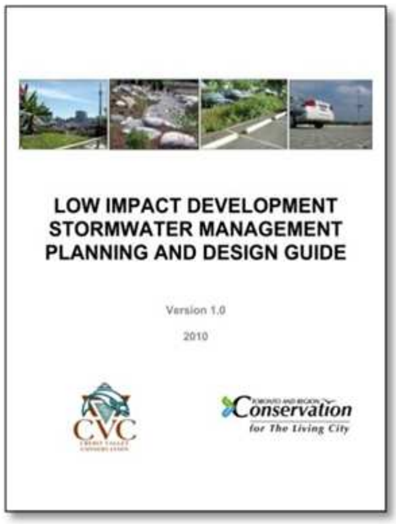
While still a significant improvement over pre-1980 stormwater practices, conventional SWM still falls short of protecting water resources. CVC's extensive integrated watershed-wide monitoring has shown that the environmental health of our water resources has continued to decline as urbanization increases, despite the use of conventional end-of-pipe SWM facilities. Monitoring results within the Greater Golden Horseshoe and across the US have found that conventional SWM, which focuses on controlling peak flow rate and the concentration of suspended solids (mainly through end-of-pipe wet ponds), has failed to address the widespread and cumulative hydrologic modifications in watersheds. These hydrologic modifications increase the volume of stormwater, increase the runoff rate, and cause excessive erosion and degradation of stream channels. Conventional SWM also fails to adequately treat pollutants of concern, such as nutrients, pathogens, and metals.

One of the key findings in CVC's 2007 CRWMS Update (supported by findings from the Credit River Water Quality Strategy and Credit River Peak Flow Study) was that continued use of what are currently considered "state of the art" SWM practices – the best designed conventional SWM practices − will lead to continued degradation of the watershed. This will jeopardize the health of the Credit's world-class fishery and other valued environmental resources. To protect the health of the Credit River watershed, the updated water management strategy called for an immediate shift to more proactive and innovative SWM systems that include low impact development practices for both new development and retrofitteing of existing urban areas.

Low impact development is an approach to sustainable SWM design that attempts to achieve today's multiple water quality and hydrologic SWM goals. The term low impact development (LID) is used commonly in North America, but in other places it is referred to as better site design, sustainable urban drainage, water sensitive urban design, or stormwater source controls. The LID definition used by the CVC and TRCA has been adapted from the United States Environmental Protection Agency (U.S. EPA, 2007):

> Low impact development (LID) is a stormwater management strategy that seeks to mitigate the impacts of increased runoff and stormwater pollution by managing runoff as close to its source as possible. LID comprises a set of sites design strategies that minimize runoff and distributed, small scale structural practices that mimic natural or predevelopment hydrology through the processes of infiltration, evapotranspiration, harvesting, filtration and detention of stormwater. These practices can effectively remove nutrients, pathogens and metals from runoff, and they reduce the volume and intensity of stormwater flows.

Detailed information on LID design and practice strategies can be found in the *Low Impact Development SWM Planning and Design Guide (LID SWM Guide)* developed by CVC and TRCA as well as CVC's LID Landscape Guide. The *LID SWM Guides* are intended to augment the Ontario Ministry of the Environment (MOE) *SWM Planning and Design Manual* (2003). The MOE manual provides design criteria for "conventional" end-of-pipe SWM practices such as wet ponds and constructed wetlands but provides only limited information about lot level and conveyance controls. The MOE manual does, however, emphasize the use of a "treatment train" approach to reduce the impacts of stormwater runoff. A treatment train approach − a combination of lot level, conveyance, and end of pipe SWM practices − is usually required to meet the multiple objectives of SWM.



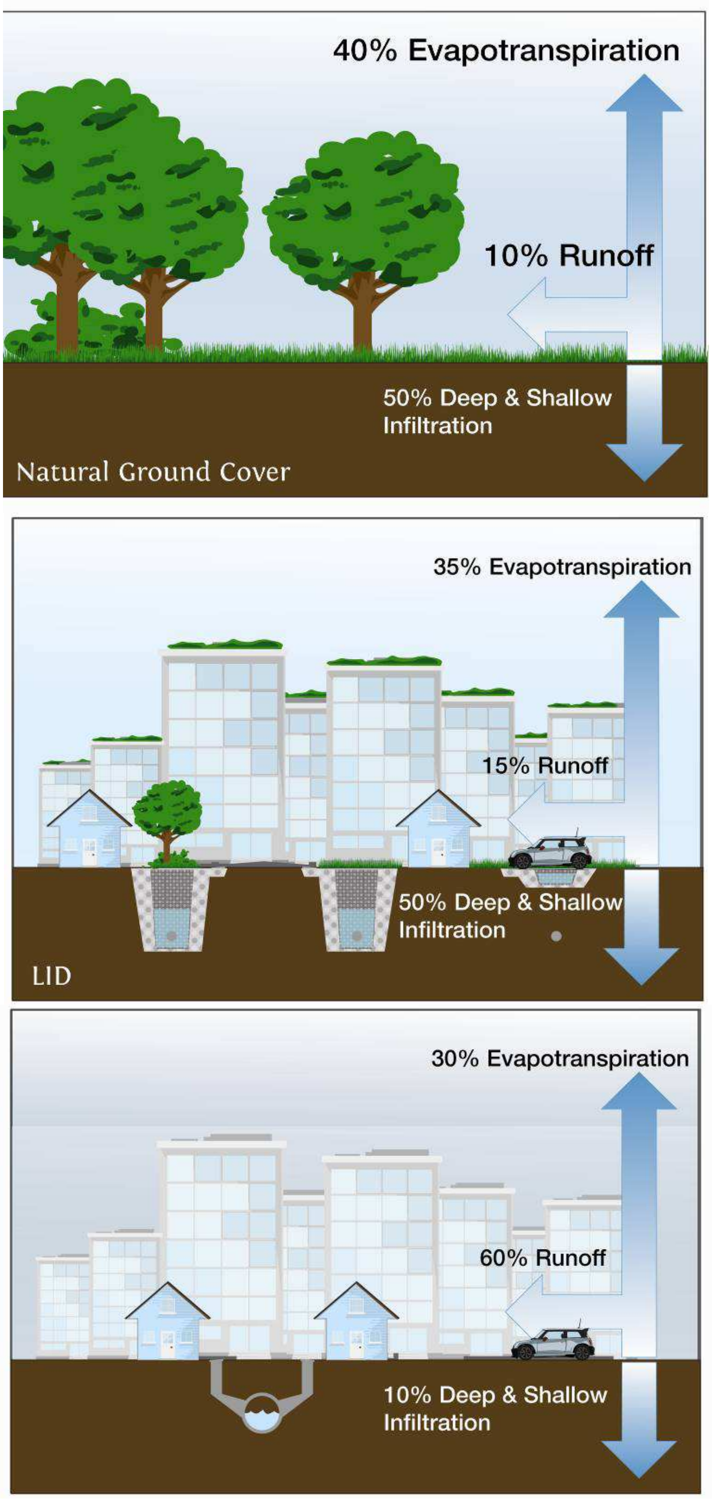


Figure 10 Water Balance Diagrams. Diagrams from top to bottom: Pre-Development, High Density Urban - Business as Usual, High Density Urban - with LID (figures created by CVC, water balance percentages from Headwaters Subwatershed Study Phase II)

Key LID Principles
Key principles for low impact development are as follows:

1. Use existing natural systems as the integrating framework for planning
- Consider regional and watershed scale contexts, objectives and targets.
- Look for SWM opportunities and constraints at watershed/subwatershed and neighbourhood scales.
- Identify and protect environmentally sensitive resources.
- See Chapter 2 of the LID SWM Guide further guidance on the landscape-based approach to SWM planning and design.

2. Focus on runoff prevention
- Minimize impervious cover through innovative site design strategies and application of permeable pavement.
- Incorporate green roofs and rainwater harvesting systems in building designs.
- Drain roofs to pervious areas with amended topsoil or stormwater infiltration practices.
- Preserve existing trees and design landscaping to create urban tree canopies.

3. Treat stormwater as close to the source area as possible
- Utilize decentralized lot level and conveyance SWM practices as part of the treatment train approach.
- Flatten slopes, lengthen overland flow paths, and maximize sheet flow.
- Maintain natural flow paths by utilizing open drainage (*e.g.*, swales).

4. Create multifunctional landscapes
- Integrate SWM facilities into other elements of the development to conserve developable land.
- Utilize facilities that provide filtration, peak flow attenuation, infiltration and water conservation benefits.
- Design landscaping to reduce runoff, urban heat island effect and enhance site aesthetics.

5. Educate and maintain
- Provide adequate training and funding for municipalities to monitor and maintain lot level and conveyance SWM practices on public property.
- Teach property owners, managers and their consultants how to monitor and maintain lot level SWM practices on private property.
- Establish legal agreements to ensure long-term operation and maintenance.

LID Site Design Strategies
The low impact development strategies described in the *LID SWM Guide* and their respective section numbers in the guide are briefly described below.

- **3.2.1. Preserving Important Hydrologic Features and Functions**: Features such as areas of highly permeable soil, pocket wetlands, riparian buffers, and tree clusters provide retention, detention, infiltration and filtering of stormwater and can in some situations be used to buffer the hydrologic impacts created by development.

- **3.2.2. Siting and Layout of Development:** The location and configuration of urban elements, such as streets, sidewalks, driveways, and buildings, within the framework of the natural heritage system provides many opportunities to minimize hydrologic impacts and preserve natural drainage patterns.

- **3.2.3. Reducing the Impervious Area**: Lot level efforts to reduce street area, building footprints, parking footprints, sidewalks, and driveways collectively lead to substantial decreases in runoff and reductions in infrastructure costs.

- **3.2.4. Using Natural Drainage System:** Rather than using storm sewer systems that collect and rapidly move stormwater to a central location, the use of natural drainage patterns and vegetated areas will extend runoff flow paths and slow down flow to allow soils and vegetation to treat and retain it.

LID Structural Practices
The low impact development practices described in the *LID SWM Guide* and their respective section numbers in the guide are briefly described below.

Table 5. LID Structural Practices

LID Practice	Photo	Description
Rainwater Harvesting		Rainwater harvesting is the process of intercepting, conveying and storing rainfall for future use, typically landscaping or other non-potable uses.

Residential rain barrel capturing roof runoff.

Green Roofs

University of Toronto - Mississauga Campus - green roof (photo credit: CVC)

Green roofs consist of a thin layer of growing medium and vegetation installed on top of a conventional flat or sloped roof and stores rainwater until it is evapotranspired by the plants, evaporates or slowly drains away.

Roof Downspout Disconnection

Photo Credit: David Elkin

Simple downspout disconnection involves directing flow from roof downspouts to a pervious area that drains away from the building and preventing it from entering the storm sewer.

Soakaways, Infiltration Trenches and Chambers

Rear lot infiltration trench under construction. (photo credit - Cahill & Associates)

Soakaways, infiltration trenches and chambers are underground stormwater infiltration practices that store runoff until it can be infiltrated into the native soils.

Bioretention

Rain Gardens are a specific form of bioretention

Green Glade Public School in City of Mississauga - bioretention cell taking parking lot runoff and roof runoff (photo credit: CVC)

Bioretention is a vegetated shallow depression, typically with an engineered soil media, that temporarily stores, treats, and infiltrates runoff.

Rain Gardens are designed to capture roof, lawn and driveway runoff from small drainage areas less than 1000 square metres.

Vegetated Filter Strips

Photo Credit: Aquafor Beech

Vegetated filter strips are gently sloping, densely vegetated areas that treat runoff as sheet flow from adjacent impervious areas.

Permeable Pavement

CVC Main Office in the City of Mississauga - interlocking concrete permeable paver lot (photo credit – CVC)

Permeable pavements, an alternative to traditional impervious pavement, allow stormwater to drain through them and into a stone reservoir where it is infiltrated into the underlying native soil or temporarily detained.

Enhanced Grass Swales

High Point Neighborhood, Seattle, WA (Photo credit - CVC)

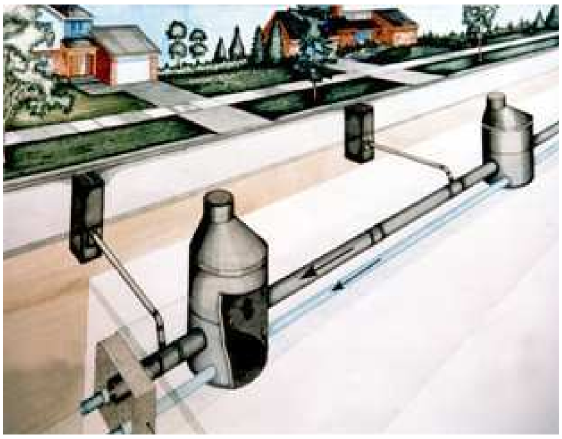
Enhanced grass swales are shallow, broad, open channels, sometimes incorporating check dams, used to convey, filter, and attenuate stormwater runoff.

Dry Swales


Lakeside Park in City of Mississauga - dry swale or bioretention swale taking runoff from parking lot. Photo credit: Seattle Public Utilities

A dry swale can be thought of as linear bioretention or as an enhanced grass swale that incorporates an engineered soil bed and optional perforated pipe under drain.

Perforated Pipe Systems


Conceptual Drawing of Perforated Pipe System

Perforated pipe systems can be thought of as long infiltration trenches that are designed for both conveyance and infiltration of stormwater runoff.

4.2 LID Monitoring Objectives

The need for LID in Ontario has been clearly presented in the LID Discussion Paper (2012) by the Greater Golden Horseshoe Conservation Areas. The discussion paper outlines three of the main reasons for why LID is important to Ontario:

- LID is an important step in attempting to re-establish the balance on which our ecosystems depend by offering improved water quality results and habitat protection for aquatic and terrestrial species.
- LID can help developers, municipalities and the province to achieve their green development goals, including the provincial objectives set out in Places to Grow and the Provincial Policy Statement (2005) and Ontario Water Opportunities Act (2010).
- LID, as a distributed system, offers more resilient infrastructure than conventional, larger end-of-pipe facilities. MOE's *Policy Review of Municipal SWM in Light of Climate Change* concludes that resilient systems are necessary to strengthen municipalities' ability to adapt to climate change.

As with all SWM systems, whether conventional or new, LID needs to be monitored for a variety of reasons. The objectives outlined in this section are based on barriers and issues raised by Ontario stormwater stakeholders and CVC's partners. The main barriers include:

- Credits and costs of LID - LID is seen by the development community as an add-on to the conventional end-of-pipe approach. Refinement of environmental regulatory credits for LID is needed to allow for the reduction in pond sizes and potential elimination of the water quality/wet component of the pond. LID can allow for more buildable space and design solutions for sites where an end-of-pipe solution is impractical.
- Long term experience with LID in Ontario - While there are many examples of successful LID projects implemented in Ontario and cold climates of the US that are 15+ years old, there are still concerns about how these systems will function over their life cycles.
- LID maintenance on private property - LID often entails a combination of public and private responsibilities. Further monitoring of LID is needed to better define the maintenance requirements and the mechanisms for ensuring that it is completed.

CVC is actively partnering with the suppliers, development community, municipalities, and the province to optimize the use of monitoring resources to address multiple objectives and barriers. This ensures that the monitoring data collected from development sites is used and moves SWM forward in Ontario. To date (2012) CVC has collected $3.8 million and in-kind contributions to meet our objectives. The project is funded by MOE's Showcasing Water Innovation (SWI) grant and financial and in-kind support from many industry and public partners. SWI is the MOE's program that funds innovative and cost-effective green technologies to ensure clean and abundant drinking water for Ontario residents. The project monitors LID retrofits in the public land, right-of-way, residential, and commercial/industrial sectors. While improving LID retrofit decision-making for municipalities, the projects monitored also address critical barriers.

CVC's objectives for monitoring LID systems fall within CVC's mandate to monitor SWM for compliance, performance, and adaptation.

- **Compliance** monitoring focuses on assessing whether the facility is built as designed and whether it meets minimum acceptable regulatory requirements.

- **Performance** monitoring measures how well (or poorly) a SWM practice performs according to design objectives and targets. These studies are typically undertaken when little information is available regarding the effectiveness of a certain type of facility in a certain environmental context.

- **Adaptive** monitoring assesses how SWM practices can be improved to improve water quality, meet hydrologic goals, last longer, be maintained better, and provide ancillary benefits (i.e. reduce urban heat island or improve aesthetics).

The Table 5 identifies CVC high level monitoring objectives for LID systems and categorizes them by type of monitoring. The objectives relate to both meeting stormwater criteria and improving the functionality and long term performance of LID practices in the southern Ontario context. In Table 6, rationales for the objectives and example studies are provided for each objective.

Table 4 Compliance, Performance, and Adaptive Monitoring Objectives for LID SWM

LID SWM Monitoring Goals	Compliance	Performance	Adaptive
1. Evaluate how SWM ponds perform with LID upstream. Can the wet pond component be reduced or eliminated by meeting the erosion and water quality objectives with LID?	X	X	
2. Assess performance of measures to determine potential rebates on development charges, credits on municipal stormwater rates and/or reductions in flood insurance premiums. (i.e. can LID reduce infrastructure demand).		X	
3. Evaluate whether LID SWM systems are providing flood control, erosion control, water quality, recharge, and natural heritage protection as per the design standard.	X		
4. Evaluate and refine construction methods and practices for LID projects.			X
5. Evaluate long-term maintenance needs and maintenance programs, and the impact of maintenance on performance.		X	X
6. Evaluate effectiveness of soil amendments and increased topsoil depth for water balance and long-term reliability.	X	X	
7. Assess the potential for groundwater contamination in the short and long term.		X	
8. Assess the performance of LID designs in reducing pollutants that are dissolved or not associated with suspended solids (i.e. nutrients, oils/grease, and bacteria)		X	
9. Determine the life cycle costs for LID practices			X
10. Demonstrate the degree to which LID mitigates urban thermal impacts on receiving waters	X	X	
11. Assess the water quality and quantity performance of LID designs in clay or low infiltration soils and those that do not use infiltration.	X	X	
12. Assess the water quality and quantity performance of LID technologies		X	
13. Evaluate how a site with multiple LID practices treats stormwater runoff and manages stormwater quantity as a whole.	X	X	
14. Assess the potential for groundwater mounding in localized areas.		X	
15. Assess the potential for soil contamination for practices that infiltrate.		X	

16. Assess the ancillary benefits, or non-SWM benefits.		X	X
17. Develop and calibrate event mean concentrations (EMCs) for various land uses and pollutants.	X	X	
18. Improve and refine the designs for individual LID practices.		X	

Table 5 Additional background on LID SWM Monitoring Goals

Objective	Rationale for Monitoring Objective	Examples of Monitoring Studies
1. Evaluate how SWM ponds perform with LID upstream. Can the wet pond component be reduced or eliminated by meeting the erosion and water quality objectives with LID?	*This objective is included in both the LID and conventional objectives sections as it is a high priority and relates to both.* Installation of LID practices in a site may allow "downstream" wet ponds to be reduced in size. For developers, a reduction in the pond size or elimination of the wet component would allow for more land that is developable. It would also mean that municipalities would not have to pay for expensive dredging every 8 to 10 years, but rather have annual landscape maintenance. An acceptable method for resizing stormwater ponds needs to be established in cases where LID practices are used upstream to treat runoff and reduce volumes. SWM approval agencies in the US have different methods for resizing ponds with upstream LID such as adjusting runoff coefficients or requiring continuous modeling, but an Ontario-specific method needs to be developed.	This objective can be evaluated by either conducting a water balance on the pond with LID upstream or alternatively by monitoring the flows from the downstream outlet from an LID system. *See Appendix, Meadows in the Glen Monitoring Plan*
2. Assess performance of measures to determine potential rebates on development charges, credits on municipal stormwater rates and/or reductions in flood insurance premiums.	Municipalities are exploring ways to more equitably collect revenue to fund their SWM programs and how to incentivize development design that reduces stress on the municipal infrastructure. The current property tax funding does not take into account the amount of stormwater that the property generates. Charging stormwater user fees to property owners based on impervious area, an indicator of stormwater generated, would allow the city to offer credits or rebates based on reduced impervious area or onsite SWM. How to translate swm systems into varying levels of credit needs to be evaluated. Better performance understanding of SWM will provide meaningful information to municipalities to establish appropriate SWM rate credits. Also, there is the potential for rebates should homeowner flood insurance be adopted.	Performance monitoring that determines the reduction in stormwater impacts from various property types can be used to set credits and rebates. *See IMAX, CVC Main Office, Portico Church, Riverwood, Alton Residential, Green Glade Public School, Elm Dr. and Lakeview monitoring projects.*

Objective	Rationale for Monitoring Objective	Examples of Monitoring Studies
3. Evaluate whether LID SWM systems are providing flood control, erosion control, water quality, recharge, and natural heritage protection as per the design standard.	Evaluation of whether a new swm system complies with minimum regulatory requirements is the responsibility of the developer of the facility. A typical timeframe for demonstrating that requirements have been met range from 2 to 5 years following construction. The extensive body of monitoring studies on LID has given the stormwater community a high level of confidence that LID designs can achieve erosion control, water quality, thermal, and water balance goals that conventional centralized controls cannot. LID also has the potential to reduce flood impacts, particularly in urbanized areas where there is no space for centralized flood control facilities.	The study of an LID system presents challenges as there is often not one inlet to measure quantity and quality, but there is typically one outlet. System performance can be evaluated by monitoring at the outlet and using precipitation data and pollutant loading data to determine inputs. *See Appecndix, Walnut Grove, Elm Dr., Lakeview, and IMAX LID Monitoring Plans.*
4. Evaluate and refine construction methods and practices for LID projects.	Well-designed LID systems can often fail or become diminished because of poor construction. This can be the result of plans without enough detail or contractors that do not understand the technology or function of certain procedures and materials or the importance of erosion and sediment control (see *Designer's Guide for Low Impact Development Construction* (draft posted to CVC website Sept 26, 2011). The *Designer`s Guide* alerts engineers to common LID failures and how to avoid them through proper planning, siting, contractor communication material specification guidance and protection during all phases of construction.	LID projects undertaken by CVC or in partnership with CVC should be observed for the effectiveness of construction methods and materials and post-construction functionality. The lessons learned from observations and new methods can be refined over time and then incorporated into guidelines, draft plan conditions, permits, and bylaws. *See Elm Drive, Porico, Lakeside, IMAX and Lakeview Construction Lessons Learned Case Studies.*

Objective	Rationale for Monitoring Objective	Examples of Monitoring Studies
5. Evaluate long-term maintenance needs and maintenance programs, and the impact of maintenance on performance.	Many municipalities are already struggling with monitoring and maintaining SWM ponds and the stormwater drainage network. Ensuring the maintenance and function of many distributed LID practices that have a mix of public and ^private owners will be an even more difficult challenge. One of the benefits of using LID is that losing one or two practices in the network does not result in the catastrophic consequences that the failure of a wet pond might. In addition, studies of LID practices (such as bioretention) have found them to be resilient in their ability to function without maintenance and to restore themselves. In some cases, the performance may improve with time as vegetation becomes established. Monitoring to address this objective will help to refine design factors for safety and determine the best policy approaches (i.e. easements or deed restrictions) for keeping LID practices in place and maintained.	Whatever maintenance arrangement is applied, SWM pond owners should keep an inspection and maintenance log. This is critical to better understand the maintenance requirements of LID practices in an Ontario setting. These records may include such factors as the frequency of litter and debris removal, draw down times, and vegetation health. The information collected through inspection and maintenance records may then be paired with quantitative flow and water quality monitoring to allow for an evaluation of maintenance on long-term performance. *See Appendix, Elm Drive Green Street Project.* - Catchbasins are being used as the pretreatment practice for the Elm Drive bioretention planters. The buildup in sedimentation inside the catchbasins over time will determine how frequently they must be cleaned out. Also s*ee MOE SWI projects for retrofitting ROWs and Public Lands, Lakeview and IMAX.*
6. Evaluate effectiveness of soil amendments and increased topsoil depth for water balance and long-term reliability.	Soil amendments are used in many LID sites to improve the infiltration capacity of poorly draining native soils or restore soils that have been compacted or lost their structure during construction. This SWM technique is popular among designers because it allows for a greater initial retention of rainfall on-site. Soil amendments offer the potential to lower the hydrologic soil group for modeling and thereby reduce the size and costs of SWM facilities. However, the implementation and maintenance of amended soil is problematic. The *LID Design Guide* specifies compost as an amendment while other design engineers argue for an increased depth of topsoil. It should be noted that the quality of topsoil can vary widely and in many areas of CVC the topsoil has high clay content. Furthermore, there are no assurances that a soil-amended area will not be later be compacted or covered by impervious surfaces.	CVC will be collecting consultant data on the proper installation at Walnut Grove and Mount Pleasant development sites. Post-construction monitoring in the form of test pits and rod penetrometers is needed to measure compaction. The performance of the practice will be monitored as a group of LID practices for both of these developments. A study that compares the hydrologic benefits of sites with differing topsoil composition may be a useful complement to the study on topsoil depths. Properties that have had soil amendments or increased topsoil for a long period could be surveyed to evaluate the extent of increased impervious cover and compaction over time.. TRCA STEP is currently studying stormwater retention in residential catchments with varying topsoil depths (10 cm, 30 cm, and 120 cm).

Objective	Rationale for Monitoring Objective	Examples of Monitoring Studies
7. Assess the potential for groundwater contamination in the short and long term.	Practices such as bioretention and dry swales provide settling and filtering before stormwater enters the subsoil, but other practices like soakaway pits and permeable pavement may only provide limited settling and filtering before stormwater enters the subsoils. The subsoils are actually considered to be part of the treatment system as most pollutants are captured in the first few inches of soil. However, chlorides once dissolved into stormwater are very difficult to capture and will move through the subsoil. There are also indications that dissolved chlorides may mobilize other pollutants that have been captured in the subsoils. Stormwater managers in areas of high recharge like Orangeville are comfortable with the infiltration of clean water sources such as roof runoff, but they are less comfortable with the infiltration of runoff from parking lots and streets.	Studies addressing this objective should observe stormwater contaminant movement to and within groundwater for various practices capturing runoff from different land types (i.e. parking lot or high pollutant generating areas and rooftops or clean runoff/third pipe areas). The conclusions from these studies may guide what runoff may be infiltrated in groundwater protection zones or the level of pretreatment or filtering necessary before runoff enters the subsoils. *See Appendix, Meadows in the Glen, IMAX and Walnut Grove Monitoring Plan.*
8. Assess the performance of LID designs in reducing pollutants that are dissolved or not associated with suspended solids (i.e. nutrients, oils/grease, and bacteria)	The major shortcoming of conventional centralized SWM pond systems is that they do not adequately address pollutants that are dissolved or not associated with total suspended solids. LID as a source control and water balance strategy has been found to address these types of pollutants better than centralized pond systems. Additional regional monitoring data on how LID practices (and conventional SWM practices) treat these pollutants is necessary to meet current and future pollutant reduction goals.	Monitoring for dissolved pollutants, chlorides, phosphorus, and nitrogen, requires more extensive lab analysis. *See Appendix, Elm Dr, IMAX, Walnut Grove, Meadows in the Glen, and the Lakeview Monitoring Plans*. These sites monitor the performance of SWM practices for a full suite of pollutants including dissolved pollutants.
9. Determine the life cycle costs for LID practices	Regional, easily accessible life-cycle costs will raise the comfort level of developers, owners, engineers, and regulators with the implementation of LID approaches for managing stormwater. Installation costs, the cost of routine and remedial maintenance activities and eventual replacement costs needs to be documented. The costs of LID practices can vary widely based on site and market conditions, but the collected cost data can provide a baseline and show that LID sites can be cost competitive with sites serviced with conventional SWM facilities.	Collecting project budget information from developers and contractors can be difficult due to market competition issues. Projects associated with non-profits and religious institutions or those that are funded by the CVC will be the best sources for collecting detailed life cycle cost information. *All of the CVC LID monitoring projects will include a life cycle analysis component.*

Objective	Rationale for Monitoring Objective	Examples of Monitoring Studies
10. Demonstrate the degree to which LID mitigates urban thermal pollution	Directly connected impervious surfaces without source controls, as well as stormwater ponds, generate thermal pollution. The use of LID practices that bring urban runoff in contact with subsoils and vegetation as well as restore the water balance will reduce the thermal pollution released to surface waters.	An example study would be one that continuously measured the temperature of runoff coming from an LID SWM site and an equivalent conventional SWM site. See IMAX, Walnut Grove, Elm Dr. and Meadows in the Glen monitoring plan.
11. Assess the water quality and quantity performance of LID designs in clay or low infiltration soils and those that do not use infiltration.	Currently, the *2003 MOE SWM Planning and Design Manual* does not recommend infiltration type SWM practices in low infiltration soils (<15 mm/hr). It also does not give water quality credits to source control LID practices that use treatment mechanisms other than infiltration, such as bioretention with underdrains. Available studies on LID in clay soils or lined LID practices have found better than expected runoff reductions and high levels of treatment. Typical removal efficiencies should be determined in local soils and climate.	Given the predominance of clay soils in the lower part of the CVC watershed, many LID practices will be located over these soils. To accurately determine the pollutant load capture and volume reduction, runoff will need to be monitored at the inlet and the underdrain and overflow outlet(s). *See Appendix Elm Drive, Lakeview and IMAX Monitoring Plans*. These studies will evaluate volume reduction and flow attenuation from permeable pavement and bioretention sites overlaying clay soils.
12. Assess the water quality and quantity performance of LID technologies, which currently do not receive credits or are only given limited credit in the 2003 MOE SWM SWM Planning & Design Manual..	The *2003 MOE SWM Planning and Design Manual* currently gives water quality credits to stormwater practices that infiltrate into soils. Rainwater harvesting and green roofs are both included in the *LID Design Guide* but are not given SWM credits for either water quality or volume reduction or are only credited in terms of curve numbers or runoff reduction factors. Likewise, bioretention practices that only filter runoff are also not given water quality credit in the *2003 MOE SWM Planning & Design Manual*. The use of these practices with a wet detention pond may result in oversizing of the pond.	Green roofs and rainwater harvesting systems are growing in popularity and there are many sites available to monitor in the CVC watershed. *See CVC Office Addition Monitoring Plan* - The rainwater harvesting system for the CVC building will be monitored for year round consistency in use and to quantify how much volume leaves the site when the tank is full.

Objective	Rationale for Monitoring Objective	Examples of Monitoring Studies
13. Evaluate how a site with multiple LID practices treats stormwater runoff and manages stormwater quantity as a whole.	Because LID is distributed source control that uses a treatment train approach, there are a number of unique LID designs and many combinations of practices that could be used in sites and subdivisions. While LID literature reviews find many studies of the individual LID practices, there are few studies of LID systems. Monitoring at the discharge point(s) of a site with multiple LID practices will give regulators and designers a better understanding of how LID practices work together and their environmental benefits. This will also help to calibrate the modeling of LID systems.	Many of the CVC monitoring sites involve monitoring multiple LID practices on a site or monitoring LID practice in series. *See Appendix, CVC Office Addition, Meadows in the Glen, Lakeview, Elm Drive, Walnut Grove and IMAX Monitoring Plan*s.
14. Assess the potential for groundwater mounding in localized areas.	LID practices attempt to compensate for infiltration lost from impervious areas by concentrating infiltration in one location. A common concern arising from this is the potential for groundwater mounding. Areas of high groundwater may affect nearby utilities, pavement, and foundations through freeze/thaw action and frost heaving. Studies investigating this objective should assess how serious the risk of groundwater mounding is and if distributing the practices more (making the drainage areas for each practice smaller) will adequately reduce localized mounding.	The depth of groundwater under a new development will be monitored for changes before construction, through construction and post construction when all infiltration practices will be online. *See Appendix Meadows in the Glen, Walnut Grove and IMAX Monitoring Plans.*
15. Assess the potential for soil contamination for practices that infiltrate.	Another concern for LID is that stormwater pollutants will collect in many locations around a site rather than a central stormwater pond location. This raises concerns about people coming into contact with contaminated soils in these areas and also whether the soils will need special treatment when the practice is being maintainedremediated or redeveloped. Due to the fact that LID is small-scale and distributed, LID practices will be accepting runoff from relatively small areas and relatively small amounts of pollutants are expected to accumulate. Small concentrations of pollutants can be more easily broken down, treated and absorbed by soils and plants. Analysis of soils in the bioretention and under the permeable pavement of parking lots has not found high pollutant concentrations that would warrant special handling or disposal of the soil.	In the monitoring plan, soils are tested in the parking lot bioretention for contaminants of concern after installation and then again every 1 to 2 years to observe the increase of contaminants in the soil. *See Appendix, IMAX, Public Lands, Elm Dr. and Riverwood Monitoring Plans.*

Objective	Rationale for Monitoring Objective	Examples of Monitoring Studies
16. Assess the ancillary benefits, or non-SWM benefits.	LID is integrated into the urban form, within landscaped spaces and in the right-of-way. Most LID practices offer benefits beyond just SWM. Vegetated practices clean and cool air and sequester carbon. Permeable pavements are cooler and absorb vehicle sounds. Rainwater harvesting reduces energy costs associated with water treatment and transport.	To evaluate the urban heat island, measurements of continuous air temperature differences between conventional urban surfaces and LID urban surfaces (permeable pavement and bioretention areas) can be conducted. To evaluate water conservation, CVC is monitoring the reduction in municipal water usage with a rainwater harvesting system. See *Appendix CVC Office Addition Monitoring Plan*
17. Develop and calibrate event mean concentrations (EMCs) for various landuses for TSS, phosphorous, chloride, copper, zinc, nitrate/nitrite, total nitrogen, and E-coli.	Establishing EMCs for various landuses within the watershed allows for accurate pollutant loading estimates without having to do sample collection and measurement at every site. Calibrated EMCs are needed for stormwater quality models that are consistent and accurate. They are also useful in the analysis of LID practices as they can be used for estimating inflow water quality instead of taking physical samples. For most LID sites the inflow is sheet flow or distributed and cannot be monitored.	Aquafor Beech produced summary tables of EMCs from various studies in the US and Ontario. The EMCs collected by CVC from unmanaged drainage areas or taken from inflow to SWM systems can be used to verify and calibrate the EMCs for our region. The Mississauga Valley Community Centre, Lakeview control street and IMAX control catchment can be used to establish EMCs. Further monitoring is required.
18. Improve and refine the designs for individual LID practices.	The *CVC/TRCA LID Design Guide* and *CVC LID Landscape Design Guide* was developed with the latest published LID research. As technologies change and more LID sites come online in the Credit River watershed and elsewhere, performance monitoring will become a critical component to improving designs long term and refining construction specifications for LID practices. As such, the Guide is considered a living document and will need to be updated periodically to reflect the growing body of knowledge.	Table 6 shows examples of how monitoring data is informing our understanding and enhancing design for each of the LID practices contained in the *CVC/TRCA LID Design Guide and CVC LID Landscape Design Guide*.

Table 6 **Examples of how performance monitoring can help inform LID landscape and design**

LID Type	Examples of performance monitoring informing LID deign
Rainwater Harvesting	Determine which form of pretreatment (i.e. first flush diverters, in-ground filters, in-tank filters) is most effective for the removal of sediment and debris and most easily maintained by the user.
Green Roofs	Evaluate which plants in the *CVC LID Landscape Design Guide* green roof plant list are most successful (in terms of health and denseness) on an extensive green roof in Credit Valley environmental conditions.
Downspout Disconnection	Refine the recommendation for downspout discharge (a 3-meter distance from foundations and a minimum flow path over a pervious area of 5 metres).
Soakaway Pits, Infiltration Trenches and Chambers	Evaluate the buildup of fines within the facility to determine when the infiltration storage space needs to be replaced or cleaned out.
Bioretention	Evaluate variations on the bioretention soil mix for effective removal of pollutants and determine if different soil mixes and depths should be used under different conditions (i.e. a shallow sandier mix can be used for rooftop runoff while a deeper loamier mix should be used for parking lot runoff). Evaluate plant survival and maintenance requirements to update and refine the *CVC's LID Landscape Design Guide*.
Vegetated Filter Strips	Refine the length a filter strip needs to be to provide adequate pretreatment for an infiltration type practice.
Permeable Pavement	Evaluate the reduction in salt use for permeable pavement versus impervious pavement for the same level of service.
Enhanced Grass Swales	Determine which check dam designs are most effective at withholding flows for infiltration.
Dry Swales	Study which dry swale covers (i.e. grass, mulch, and stone) can best withstand surface flows, provide treatment and meet aesthetic expectations.
Perforated Pipe Systems	Determine what adequate pretreatment is for perforated pipe systems, grass swales, catch basin sumps, or proprietary vortex devices.

5.0 MONITORING POLLUTION PREVENTION PRACTICES

5.1 Overview of Pollution Prevention

One of the key findings of the 2007 CRWMS Update was that “there are areas within the watershed that are showing signs of environmental decline [where] we need to restore existing land uses”. To address this finding CVC, in partnership with the Cities of Mississauga and Brampton, initiated three urban watershed studies with the goal of identifying restoration opportunities to protect and enhance water quality and quantity. These urban watersheds are Cooksville Creek, Sheridan Creek and Fletcher’s Creek.

In the characterization phases of these watershed studies, CVC and project partners completed pollution prevention (P2) surveys for commercial, industrial, municipal and institutional lands to look for activities and practices that could result in pollutants entering the storm drainage system, receiving watercourses and ultimately Lake Ontario. Potential threats to surface water could include outdoor fueling stations (i.e. those that are not covered or lack spill containment features), outdoor material storage areas, outdoor vehicle washing areas, places where fertilizers and pesticides are applied, and areas where rock salt is used and snow is dumped, among others. Figure 13 illustrates typical activities that occur in urban areas that have the potential to pollute stormwater runoff.

What is Pollution Prevention?

“the use of processes, practices, materials, products, substances or energy that avoid or minimize the creation of pollutants and waste, and reduce the overall risk to the environment and human health."

Canadian Environmental Protection Act, 1999

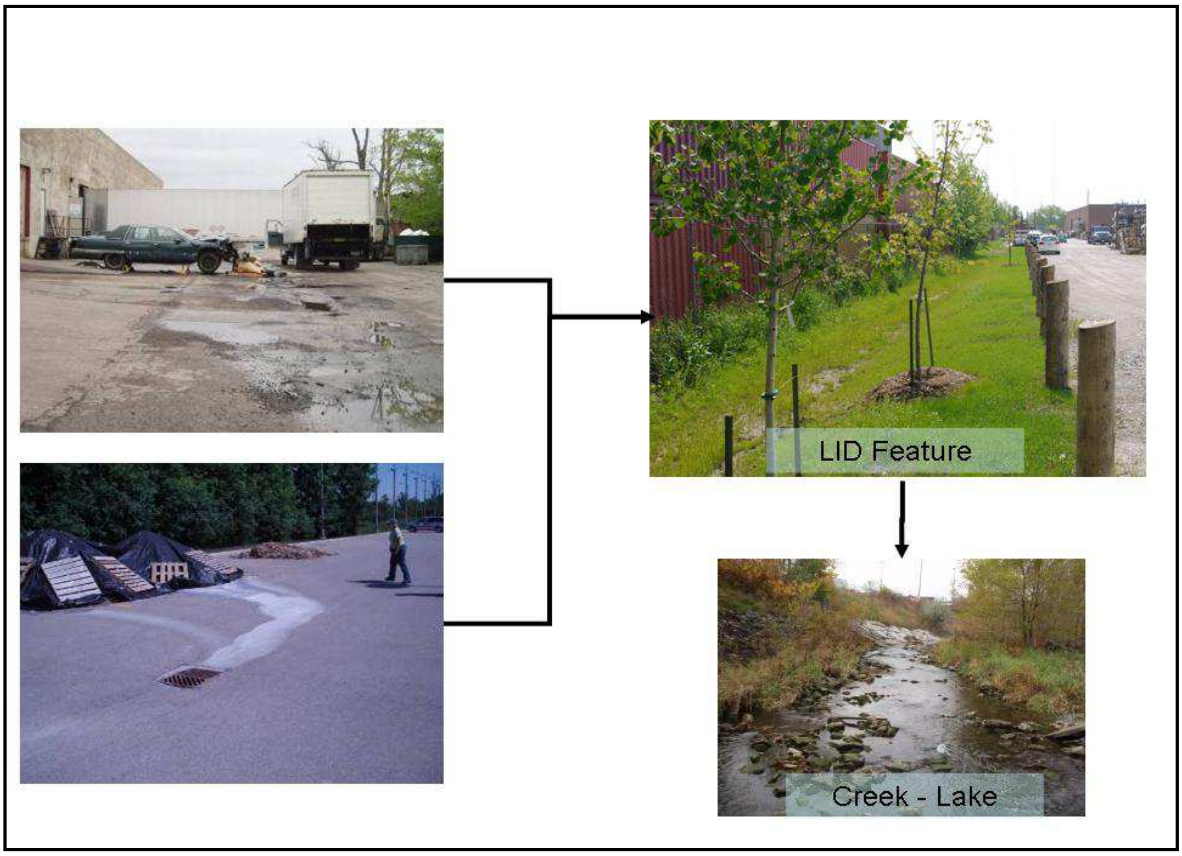
Figure 13 Different types of activities that have the potential to pollute stormwater

Why is P2 important for LID?

Protecting surface water quality by preventing pollutants from coming into contact with rainwater and snow melt runoff is considered the first line of defense. It is much easier and less costly to prevent pollutants from coming into contact with stormwater rather than treating it after the fact.

Pollution prevention compliments LID by ensuring that the cleanest water possible is reaching the LID feature thus optimizing performance, reducing future maintenance needs and preventing surface and groundwater contamination. SWM practices that receive heavily polluted stormwater will require maintenance sooner and will not perform as well. Further, infiltration based LID techniques, may put groundwater at risk if proper P2 measures are not in place.

Figure 14 Why Is Pollution Prevention Important to LID?



Pollution Prevention Partners

The threats to surface water quality highlighted in Figure 13 are also identified as being key drinking water threats in the Province's Source Water Protection Planning initiative in specified areas. Because of this, CVC received funding from Ministry of the Environment to build upon and enhance the pilot pollution prevention technical assistance program. The program includes the implementation of "in the ground" pollution prevention measures that will reduce or eliminate threats to municipal drinking water supplies at the source. This included the installation of pollution prevention measures at three businesses in Mississauga that went "above and beyond" the standard practices currently in place. The key objectives of CVC's Pollution Prevention (P2) Projects are to:

- Remove and reduce threats to surface water and municipal drinking water supplies;
- Empower stakeholders to take action and protect municipal drinking water supplies through implementation of on the ground projects;
- Increase public and community awareness of the importance of pollution prevention and making the connection between stormwater drainage and municipal drinking water supplies;
- Gain knowledge and experience that can be applied to future watershed studies pertaining to innovative pollution prevention and protecting surface water municipal drinking sources.

For more information about the demonstration sites, fact sheets and general information about Pollution Prevention please visit CVC's website http://www.creditvalleyca.ca/sustainability.

Pollution Prevention Practices

The different types of Pollution Prevention practices described in the fact sheets and case studies on CVC's pollution prevention website are briefly described below.

P2 Practice and/or Activity	Description
Illegal Dumping	Many businesses are faced with the challenge of controlling waste being illegally dumped after regular business hours. This can be attributed to a lack of understanding about the environment and how pollutants can come in contact with stormwater. Educational and warning signage can help to educate the landowner, employees and general public about the importance of protecting water quality and the consequences of illegal activities. Further, fencing off vulnerable areas further discourages illegal behavior.
Spill Diversion (Post Indicator Valve)	Liquids are often stored near loading docks, which usually contain a catch basin. Trucks also load and unload materials in this location, so any spill would drain directly into the catch basin, which then drains into local creeks. Post indicator valve (PIV) can be installed in the storm sewer pipe

	between the catch basin and loading dock. As part of loading procedures, the valve can be shut when the loading dock is in use. If a spill happened, it would be contained between the PIV and catch basin, preventing it from reaching waterways.
Spill Containment Sumps	Spill containment sumps can be placed around bulk loading and unloading areas and fuel stations to contain spilled materials. The sumps are impervious and materials can be cleaned up using dry or wet methods.
Dumpster Management	Dumpsters are a common fixture in urban environments and if not properly maintained can result in pollutants washing into storm sewers. Landowners are encouraged to replace old cracked dumpsters to prevent fluids from escaping and entering the stormsewer. A properly sized dumpster prevents the lid from being left open and discourages waste from being piled beside the dumpster and thus coming into contact with stormwater.
Material & Waste Storage	Use of storage drums placed on a spill containment pad for proper storage and disposal of waste oil. This also includes ultimate disposal off site, where to dispose and the applicable regulations that apply. Using appropriate cabinets for safe storage of paints and solvents.
Grease Management	Grease is a common by-product of food preparation facilities and can cause issues with both the storm and sanitary sewer systems. Use of appropriate grease containers with secondary containment will help to avoid contact with stormwater.
Parking Lot Maintenance	Apply sensible maintenance operations to prevent stormwater contamination. Use dry cleaning methods over power washing with caustic cleaners that can deliver nutrients, sediment and hydrocarbons to the stormwater infrastructure. If power washing parking lots with cleaning agents is required, then divert drainage to the sanitary sewer system. Post Indicator Valve's may be a feasible way to shut off the stormsewer system and then pump the wash water to a holding tank or sanitary connection.
Vehicle Washing	Vehicle wash water may contain sediments, phosphorous, metals, oils and grease. Wash vehicles indoors, use biodegradable cleaners or on a wash pad that has a containment system.
Snow & Ice Management	Often times winter de-icers are applied indiscriminately assuming that more is better. Clearing as much snow as possible before adding de-icer, divert rainwater away from walkways and driveways and considering alternatives to rock salt are all better management practices.
Landscaping & Grounds Care	Poor landscaping practices can generate organic waste, excess irrigation water, nutrients, pesticides and sediment loads to stormwater and LID practices. Improved practices are generally adopted by educating, training and certifying workers.
Building Maintenance	Many routine practices used to maintain the walls, floors and rooftops of buildings can cause stormwater pollution such as window washing, power washing, painting and sanding. These types of activities can result in sediment, metals, hydrocardons and other potentially toxic materials coming into contact with stormwater. Putting down tarps, sweeping up after paint scraping and sanding or directing wash water to the sanitary sewer are all pollution prevention opportunities.
Education	Education is a preventative measure that helps to raise awareness and understanding of how different activities affect the environment. Education helps increase environmental awareness, changes attitudes and

behaviour, and provides knowledge for making change. Education can take the form of face to face communication, educational and interpretive signage, fact sheets and case studies among others.

Winter Road Salt Monitoring

Given Source Protection concerns regarding Cl entering wells, to date, pollution prevention monitoring at CVC has focused on winter maintenance activities (road and parking lot deicing). There has been growing concern from the scientific community, municipalities, and provincial and federal governments over the use of rock salt (sodium chloride) for winter maintenance and its impact on roadside habitat, crops, aquatic ecosystems and drinking water supplies. Rock salt has been used extensively for the last half century and is highly soluble dissolving into its respective components of sodium (Na^+) and chloride (Cl^-) when coming into contact with water. As such, chloride concentrations have risen steadily within streams, rivers and lakes with no natural removal mechanisms available.

To address these issues, CVC's pollution prevention program began monitoring winter salt application in both roadways and parking lots in 2008 with an aim to quantify the mass of salt applied and to determine whether deicing alternatives have less of impact on our fresh water systems. CVC has worked with both municipalities and private organizations and results from the studies have shown the following:

- both roads and parking lots contribute significant loads of chloride due to winter salt application;
- parking lot design, contractor liability, lack of training, inefficient contracts in favor of over salting, and poor tracking of salt used all contributes to over salting
- alternative deicers do not necessarily contribute to a reduction in chloride loading.

During the winters of 2008-2009 and 2009-2010, CVC, in partnership with the City of Mississauga, evaluated the effectiveness of treated salt sprayed with magnesium chloride (MgCl) as an alternative de-icing agent to conventional winter salt (NaCl)/sand mixture. In partnership with GO Transit during the winter of 2008-2009, CVC evaluated the effectiveness of potassium chloride as an alternative de-icer. In partnership with the Town of Orangeville over the winter of 2011-2012, CVC conducted a winter maintenance study. This study looked at chloride inputs to Mill Creek from winter road and parking lot maintenance activities in residential, commercial and industrial areas and the impact of the Town of Orangeville's snow dump on the chloride levels in Mill Creek. For further information on CVC's Salt Monitoring studies please visit CVC's website http://www.creditvalleyca.ca/sustainability.

Real-time Water Quality Monitoring

The real-time water quality monitoring program was initiated at CVC in 2010. Todate, there are four real-time stations in operation. Two are located in the main Credit River, one at Old Derry Road, and the other in the Mississauga Golf and Country Club (MGCC). The other two stations are located in Fletcher's Creek at Second Line and in Cooksville Creek at King St. Each station measures the following water quality parameters:

- temperature: air temperature & water temperature
- dissolved oxygen (oxygen in water)

- pH
- conductivity and chloride
- turbidity
- water level

The data collected from real-time water quality stations provides valuable information to our municipal partners for both short and long-term environmental management decisions. Information on diurnal, seasonal, and annual variations is useful in assessing if land-use management decisions are effective and setting priorities. For example, seasonal spikes in chloride concentrations due to over-use of de-icers and residential pool drainage provide municipalities with information on priority hot spots for pollution prevention and targeting outreach and education programs. Real-time data has also proven important as an emergency response tool for detecting spills and sediment discharges from the development sites to the watercourses. Over the long-term real-time data will reveal trends in the water quality parameters and provide policy makers with data to make informed environmental management decisions with respect to mitigating risks due to climate and land-use changes.

5.2 Monitoring Objectives for Pollution Prevention

CVC's objectives for monitoring P2 sites fall within CVC's mandate to monitor SWM and runoff for compliance, performance, and adaptation.

- **Compliance** monitoring focuses on assessing whether the practice, facility or business meets minimum acceptable regulatory requirements.
- **Performance** monitoring measures how well (or poorly) a P2 practice performs over the lifetime of the P2 practice and if it continues to meet specification.
- **Adaptive** monitoring assesses how P2 practices can be improved to further protect water quality, last longer, be maintained better, and provide ancillary benefits.

The Table 5.1 identifies seven CVC monitoring objectives for P2 projects and categorizes them by the type of monitoring. In table 5.2, rationale for the monitoring objectives and example studies are provided for each objective.

Table 7 Monitoring Objectives for Pollution Prevention Practices Related to SWM

Monitoring Objectives for Pollution Prevention Related to SWM	Compliance	Performance	Adaptive
1. Evaluate whether conventional and innovative P2 practices are providing water quality protection and/or treatment.	X	X	
2. Evaluate and refine construction methods and practices for P2 projects.			X
3. Assess ongoing and long-term maintenance needs to ensure continued performance of P2 projects.		X	X
4. Evaluate the impacts of traditional winter maintenance activities	X	X	
5. Evaluate the use of alternative de-icers		X	X
6. Evaluate the effectiveness and impacts of reducing the amount of de-icing product used		X	X
7. Evaluate the effectiveness of P2 strategies on the removal of specific pollutants (e.g. how fertilizer bans affect nutrient loadings; how vehicle maintenance strategies reduce concentration of metals and oils)		X	X
8. Evaluate uptake and effectiveness of education and marketing material			X
9. Evaluate the effectiveness of P2 and construction practices using real-time Water Quality monitoring by detecting the presence/absence of spills from a site.	X	X	

Table 8 Additional Background on Monitoring Objectives for Pollution Prevention Related to SWM

Monitoring Objective	Rationale for Monitoring Objective	Examples of Monitoring Studies
1. Evaluate whether conventional and innovative P2 practices are providing the intended water quality protection/treatment	Innovative P2 practices have the potential to improve/protect (surface/ground) water quality.	CVC received funding from Ministry of the Environment to build upon and enhance the pilot pollution prevention technical assistance program by implementing "in the ground" P2 measures that will reduce or eliminate threats to municipal drinking water supplies at the source. CVC has worked with three businesses in Mississauga (and has completed innovative P2 projects on their properties. While these projects have not had extensive monitoring conducted, it may be possible to add monitoring in the future.
2. Evaluate and refine construction methods and practices for P2 projects	In order to encourage property owners to adopt P2 practices they need to be simple designs that are cost effective to construct and maintain. Results from studying this objective will help to refine design factors and determine the best policy approaches to keeping practices in place and maintained.	CVC has worked with three businesses in Mississauga and completed innovative P2 projects on their properties (CVC staff were present throughout the construction process to document any issues encountered. The lessons learned have been documented in the P2 case studies on CVC's website.
3. Assess ongoing and long-term maintenance needs to ensure continued performance of P2 projects.	Many property owners already struggle with properly maintaining their properties therefore, it is important to ensure that the maintenance and function of new innovative P2 practices does not add greatly to the ongoing requirement of property maintenance. Results from studying this objective will help to refine design factors and determine the best policy approaches to keeping practices in place and maintained.	CVC has worked with three businesses in Mississauga and completed innovative P2 projects on their properties. CVC continues to work closely with these property owners to assess maintenance needs and costs, and to ensure that the P2 practices remain in place. Landowner agreements were developed with each landowner to outline landowner obligations in terms of the need for on-going maintenance.
4. Evaluate the impacts of traditional winter maintenance activities	Chlorides are a major pollutant of concern for the Credit River and Lake Ontario. The salting of roads, drives and parking lots is a major source of chlorides that enter our waterways. There has been growing concern over the use of sodium chloride (rock salt) and its impact on roadside habitat, crops, aquatic ecosystems and drinking water supplies.	CVC's Mississauga Salt Study, CVC's GO Transit Salt Study, CVC's Orangeville Salt Study

Monitoring Objective	Rationale for Monitoring Objective	Examples of Monitoring Studies
5. Evaluate the use alternative deicers	There has been growing concern over the use of sodium chloride (rock salt) and its impact on roadside habitat, crops, aquatic ecosystems and drinking water. There are numerous alternative deicers to the old standby of sodium chloride but are they as cost effective and are they truly better for the environment?	CVC's Mississauga and GO Transit Salt Studies
6. Evaluate the effectiveness and impacts of reducing the amount of deicing product used	Due to potential liability relating to slips and falls, and road or parking lot accidents, municipalities and property managers apply sodium chloride with a "more is better attitude". Is it possible to reduce the environmental impact of winter maintenance activities by reducing the amount of sodium chloride used?	CVC's GO Transit Salt Study
7. Evaluate the effectiveness of P2 strategies on the removal of specific pollutants (e.g. how fertilizer bans affect nutrient loadings, how vehicle maintenance strategies reduce concentration of metals and oils)	The primary goal of may P2 project is the reduction of specific pollutants leaving a site. Samples can be taken of the runoff exiting a site before and after P2 projects are constructed to determine if the P2 projects are working as intended.	The existing demonstration sites in Mississauga have defined drainage outlet points that could be monitored to estimate pollutant loading rates leaving the site.
8. Evaluate uptake and effectiveness of education and marketing material	Nearly all P2 measures depend on changing human behaviors whether it is preventing spills or maintaining a stormwater treatment practice. Various marketing and education approaches have been used including signage, factsheets, and workshops. An evaluation of the right approaches for the right audience is necessary to optimize the use of outreach resources.	Laminated maintenance instructions, signage, and in the field training were provided at the Bernardi Building Supply and Unifay-Fedar Group P2 demonstration sites. An evaluation of the level of maintenance and feedback from the grounds staff will help to determine the effectiveness of the outreach methods.

Monitoring Objective	Rationale for Monitoring Objective	Examples of Monitoring Studies
9. Evaluate the effectiveness of P2 and construction practices using real-time Water Quality monitoring by detecting the presence/absence of spills from a site.	The real-time water quality stations measure key water quality indicators (dissolved oxygen, pH, conductivity, temperature, chlorides, and turbidity) continuously and send alarms instantly when any of the measured parameters read beyond the permissible limits. The real-time water quality stations help monitor for the health of the water courses and reporting spills. These stations have also been effective in monitoring effectiveness of erosion control structures at the construction sites.	There are four water quality stations running in the Credit Valley Conservation jurisdiction.

6.0 CHALLENGES AND OPPORTUNITIES

As noted in the introduction, monitoring of SWM facilities presents many challenges and potential opportunities for implementation. The challenges and opportunities have been grouped into three main areas − planning and policy, funding, and monitoring program design.

6.1 Planning and Policy Challenges and Opportunities

Challenges:

- The MOE's guidance on stormwater planning and the design of facilities is expressed in the *SWM Planning and Design Manual* (2003). However the *MOE SWM Design Manual* provides only limited guidance on compliance monitoring, assumption procedures and maintenance requirements and does not address LID practices.

- There is a lack of consistency across province to conduct monitoring of conventional SWM ponds before assumption and after assumption for regular maintenance.

- Developers have typically not been required to implement SWM monitoring in their developments as part of their Certificate of Approval or Environmental Compliance Approval. Any monitoring required by the Ministry has been minimal and monitoring programs are typically not designed to ensure design goals are met. Monitoring data gathered by the MOE has not been made public; lack of a shared database makes comparing and evaluating designs difficult (i.e. deeper, shallower, maintenance needs).

- Additional review and monitoring requirement required by MOE in the approval of LID approaches has resulted in reluctance from developers to incorporate these SWM management features in their management plans.

- Developers have been reluctant to embrace LID approaches because of lack of credit given in terms of end of pipe sizing for the practices in SWM planning.

Opportunities:

- CVC and partners can play a role in the ongoing reassessment of existing SWM design criteria as well as development of new tools and design procedures for innovative technologies.

- Performance monitoring of conventional SWM practices would enable regulatory agencies to evaluate the existing design criteria in the field. To date some of these criteria have been developed based on computer models.

- Performance monitoring of pilot LID SWM practices and technologies would allow regulatory agencies to evaluate their effectiveness and limitations. The results from such studies would help the regulating agencies better understand the credit that can be given to LID practices in SWM planning.

- Performance monitoring of SWM facilities in general (whatever type) would allow regulatory agencies to:
    - Develop standard procedures for compliance monitoring;
    - Develop standard assumption procedures;
    - Evaluate performance reduction and to provide recommendations on maintenance of SWM facilities;
    - Provide direction for future performance monitoring requirements and research needs (e.g. monitoring protocols, reporting, data analysis) and further enhancement of the existing SWM policies and guidelines.

- CVC (CAs in general) provides a link between municipal partners and the province to specify monitoring requirements for SWM facilities and systems. These could become part of the planning process (e.g.in EIR and Draft Plan conditions, etc.) for both conventional and LID SWM projects. Monitoring requirements for SWM retrofits also need to be established.

6.2 Funding Challenges and Opportunities

Challenges:

- Monitoring SWM projects is a complex undertaking that can require significant resources and involve multiple partners. At the start of a program, there can be considerable costs for program design, equipment, and equipment setup.

- Additionally, to ensure that monitoring results are not influenced by an unusual weather year, monitoring of SWM facilities needs to take place over multiple years. Since budgets are completed on a yearly basis, finding long-term sustainable funding has been a challenge.

Opportunities:

- CVC municipalities could develop partnerships with other government agencies, universities and the private sector for in kind services to address common SWM questions.

6.3 Monitoring Program Design Challenges and Opportunities

Challenges:

- Often many small LID features are designed to treat small catchments before feeding into additional features downstream. For example in a subdivision each lot may employ a permeable paver driveway or a rain garden before runoff is routed to a bioretention trench servicing a group of properties. The assemblage of monitoring stations required to track performance from feature to feature may be practically unreasonable and cost prohibitive.

- Comparing LID features from site to site is complicated as features are tailored to site specific scenarios, criteria, and objectives. It would be inappropriate to assume congruent performance across sites employing the same technology without also considering design decisions, assumptions, sizing, treatment train configuration, and specifications for all.

- Considering that sheet flow is often used to route stormwater into the LID feature, monitoring the inflow quantity or quality is not always practically possible. As a result the performance of these systems must be estimated indirectly by some other means. In many cases a reference catchment lacking stormwater controls, or pre-development monitoring data can be used to estimate typical runoff amounts and loadings. Any statistical comparison such as this requires a great deal of data to establish significant differences and a meaningful comparison.

- In greenfield applications, baseline pre-development data (i.e. runoff flow and water quality conditions) can be difficult as there may be a lack of concentrated flows (i.e. runoff over fields as opposed to a retrofit case in which catchbasins exist). This makes it is difficult to determine pre-construction versus post-construction conditions.

Opportunities:

- Typical water quality performance measures often use a direct comparison of influent to effluent such as percent removal. However, as the influent characteristics are difficult to measure, an alternative base line may be necessary for performance monitoring of LID systems. Alternative means of evaluating performance may be the use of Event Mean Concentrations (EMC's) developed statistically for similar land uses, or incorporating Total Maximum Daily Load (TMDL) allowances. Through engaging and iliciting feedback from stakeholders throughout the CVC's SWM monitoring program on monitoring results, analysis and methodologies it is hoped we can advance science and the field of SWM.

SUMMARY AND NEXT STEPS

6.4 Summary

Effective SWM is necessary to protect our streams, rivers and lakes from the impacts of urbanization, agriculture, industry and other stresses. Once focused solely on controlling the quantity of runoff, today SWM needs to address multiple issues including stream morphology, the protection of aquatic and terrestrial habitat and the protection of groundwater. As SWM approaches and technologies have continued to evolve, so has the understanding that we need to monitor them.

Municipalities, developers and landowners spend ever-increasing amounts of money on the design, construction and operation of SWM facilities and systems. Monitoring tells us whether our actions are effective and cost-effective. Compliance monitoring can help us understand whether a SWM pond or a rain garden is working as designed and whether it meets minimum acceptable regulatory standards. Performance monitoring can tell us how well a green roof or an infiltration basin performs, relative to design objectives and targets. Adaptive monitoring can tell us how to enhance SWM facilities to better protect water quality or be more durable.

The *CVC SWM Monitoring Strategy Report* provides:

- an overview of CVC's three-tiered monitoring system that has been designed to measure environmental conditions at three scales − the watershed, the catchment and the site;
- overviews of conventional SWM and low impact development practices;
- monitoring objectives for conventional and low impact development SWM practices and supporting information on how monitoring can be carried out;
- monitoring objectives for pollution prevention (P2) projects;
- challenges associated with monitoring SWM facilities and systems along with the many opportunities that currently exist;
- overviews of eight different SWM monitoring programs taking place in the Credit River watershed; and
- references and sources of additional information.

The *CVC SWM Monitoring Strategy Report* is intended to guide the development of future SWM monitoring programs.

6.5 Next Steps

This report is a living document and will be updated as monitoring data needs adapt to meet our understanding of LID and partner needs for wider application of LID in Ontario. Current priority actions for moving forward are listed below:

- Create a stakeholder steering committee to elicit feedback on monitoring objectives, protocols, methodologies, analysis of results, data sharing and mechanisms for implementing results. The Steering Committee will include representatives of municipalities, developers (BILD), consulting, academia, and agencies. The Oct 5, 2012 LID in Action Conference marked the first step in engaging stakeholders to elicit feedback on monitoring objectives.

- Develop partnerships to provide funding for long-term monitoring programs, and the sharing of resources.

- Develop a database to hold monitoring data, a protocol for database management, and a protocol for data sharing.

- Develop templates for data analysis and for reporting/communicating results to educate various stakeholders.

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APPENDIX A: CVC SWM Monitoring Program Addresses Funder Monitoring Priorities

The following tables present how CVC's swm initiatives are supported by monitoring projects and then how the initiatives achieve or support funder priorities.

How does CVCs SWM Monitoring Program meet MOE priorities?

MOE Priorities	What does MOE Need to Implement Their Priorities	CVC Initiatives	What is monitoring doing to facilitate MOE and CVC initiatives	Future Needs
Ontario Water Resources Act • Regulates sewage disposal and 'sewage works', • Prohibits the discharge of polluting materials into water supply, • Regulates permits to draw water from ground or surface water sources, • Approves and regulates wells and water works	• Under section 53 of the OWRA, stormwater is treated as sewage and requires an Environmental Compliance Approval or ECA (formerly called Certificate of Approval) as do the treatment of other wastes. For reviewing the proposed plans during approval process, appropriate technical assessment tools are required • The MOE provides technical guidance to SWM professionals through development of the Stormwater Management Practices Planning and Design Manual. The information gap associated with novel LID technologies needs to be addressed. • The MOE Stormwater Management Practices Planning and Design Manual is the baseline reference document in the review of stormwater management applications for approval. Specific design criteria and guidelines for the innovative technologies are required for the review process. • SWM in Light of Climate Change	• Criteria Document • LID Guidance • Case Study Reports • Retrofit Guide • Thermal Guide • Landscaping guide	The multi-year performance evaluation of the LID sites will be used[1]: • To determine long term average performance of the innovative technologies • To develop design criteria and guidelines for the innovative technologies • To adjust the existing design criteria for end-of-pipe facilities when LID is implemented in site level • To adjust existing SWM design criteria in Light of Climate Change i.e. changing of rain fall patterns, temperature and flooding • To develop technical assessment tools for approval process where LID is proposed • To determine the temperature reduction capability of the innovative practices • To develop design guidelines for innovative technologies to mitigate thermal impacts of urbanization. The multi-year performance evaluation and maintenance inspection of the LID sites will be used[2]: • To evaluate the performance reduction over time and impact of maintenance on performance • To develop inspection and maintenance protocols for the innovative technologies • To evaluate plants success rates in LID **Notes:** • As indicated in the MOE guidelines, to develop the water quality design criteria for current MOE manual, the average annual TSS removal efficiency of a SWMP with a certain volume of storage has been determined using continuous simulation and a sedimentation model. • During development of MOE manual, the required maintenance frequency for the SWMP has been determined based on the annual sediment accumulation and resulting annual loss in storage.	• According to the MOE guidelines, "The levels of protection correspond to the 'long-term average suspended solids removals' which refer to the removal by the SWM facility of suspended solids from the site runoff for the entire range of rainfall events on that site for a long period of time, at least 10 years. The use of a long-term average is to account for the variability in characteristics of rainfall events". • 10 years of monitoring provide sufficient data to determine the long term average performance of a pilot site however, to develop a set of design criteria, it is essential to determine performance of a particular technology as function of geometry, construction material and construction methodology. For this purpose, multi-year performance evaluation of several scenarios is required. • 10 years of monitoring of pilot sites to evaluate site level long term average performance of multiple LID practices and to develop a set of design criteria for site level multiple LID practices. • Long term performance evaluation is required to examine infrastructure sizing to address the requirement for climate change adaptation.
Proposed Great Lakes Protection Act • Help restore and protect the Great Lakes so they stay drinkable, swimmable, fishable • According to the proposed act under Targets • To achieve one or more purposes of the Act, the Minister of the Environment may, after consulting with the other Great Lakes ministers, establish qualitative or quantitative targets relating to the Great Lakes-St. Lawrence River Basin, specifying in each target the area to which it applies • The Minister of the Environment may direct a public body with jurisdiction in an area specified in the direction to do any of the following: • Provide the Ministry of the Environment with any information specified in the direction to assist in establishing a target or to assist in determining the actions required to achieve a target. • Propose a target to apply to the area by working together with other public bodies. • If a target that is quantitative in nature has been established, work together with other public bodies to propose how efforts to achieve the target should be divided within the area to which it applies.	• Establish qualitative or quantitative targets relating to the Great Lakes	• Criteria Doc • LID Guidance • Integrated Water Management Urban Retrofit Guide	Results of the Real-Time Water Quality Monitoring will be used: • To establish qualitative or quantitative targets relating to the Great Lakes • To determine long term impact of implementing LID in watershed scale, on Credit River and Lake Ontario water quality • To determine long term impact of implementing CVC Stormwater Criteria document on Credit River and Lake Ontario water quality • To adjust the existing design criteria specified by the CVC Stormwater Criteria document to address targets established for the Great Lakes	• To evaluate long term impact of implementing LID in watershed scale, and to provide feedback to adjust the existing design criteria specified by the CVC Stormwater Criteria document, 10-year continuation of Real-Time Water Quality Monitoring is required • To evaluate effectiveness of implementing qualitative or quantitative targets relating to the Great Lakes , 10-year continuation of Real-Time Water Quality Monitoring is required after the targets are implemented

MOE Priorities	What does MOE Need to Implement Their Priorities	CVC Initiatives	What is monitoring doing to facilitate MOE and CVC initia
Clean Water Act (Source Protection) • Intended to help protect drinking water from source to tap with a multi-barrier approach that stops contaminants from entering sources of drinking water - lakes, rivers and aquifers	• Requires that local communities - through local Source Protection Committees - assess existing and potential threats to their water, and that they set out and implement the actions needed to reduce or eliminate these threats • Empowers communities to take action to prevent threats from becoming significant • Requires public participation on every local source protection plan - the planning process for source protection is open to anyone in the community • Requires that all plans and actions are based on sound science	• P2 • Salt Study • Case Study Reports for IMAX and MITG sites • Criteria Doc • LID Guidance	The multi-year performance evaluation of the LID sites will be use • To determine how and to what extent the LID features help to p groundwater quality. • Evaluate potential for groundwater contamination • To help address source water protection concerns about preven groundwater contamination and protect and enhance base flow contributions to receiving waterways
Ontario Environmental Protection Act (OEPA) • Promotes sustainable development to be achieved through pollution prevention and the protection of the environment and human health	• Prohibits the discharge of any contaminants into the environment which cause or are likely to cause negative effects - and in the case of some approved contaminants requires that they must not exceed approved and regulated limits • Requires that any spills of pollutants be reported and cleaned up in a timely fashion.	• P2 • Case Study Reports for monitoring sites • Criteria Doc • LID Guidance • Thermal Guide	Results of the Real-Time Water Quality Monitoring will be used: • To quantify contaminants entering the natural water bodies • To help identifying and reporting spills of pollutants in a timely • To evaluate the thermal impact of urbanization on water resou evaluate the effectiveness of thermal mitigation techniques
Ontario's Environmental Assessment Act (EAA) • Requires an environmental assessment of any major public sector undertaking that has the potential for significant environmental effects including public roads and transit, wastewater and stormwater installations. • Environmental assessments determine the ecological, cultural, economic and social impact of the project.	• The act mandates clear terms of reference, focused assessment hearings, ongoing consultation with all parties involved — including public consultation — and, if necessary, referral to mediation for decision. • Environmental assessment is a key part of the planning process and must be completed before decisions are made to proceed on a project.	• Criteria Doc • LID Guidance • Integrated Water Management Urban Retrofit Guide	Results of the Real-Time Water Quality Monitoring will be used: • To determine long term impact of implementing CVC Stormwat document for design of public infrastructure on Credit River and Ontario water quality
The Canada-Ontario Agreement Respecting the Great Lakes Basin Ecosystem (COA): • COA is an agreement between the federal and provincial governments that sets goals and objectives to restore and protect the Great Lakes basin ecosystem. That agreement in turn helps Canada meet its commitments under the Canada-U.S. Great Lakes Water Quality Agreement. Ontario signed a memorandum of cooperation with the Great Lakes and St. Lawrence Cities Initiative to support the Canada-Ontario Agreement Respecting the Great Lakes Basin Ecosystem (COA).	• Building a business case for investing in the Great Lakes • Improving stormwater and wastewater practices • Protecting beaches and coastal health	• Criteria Doc • LID Guidance • Integrated Water Management Urban Retrofit Guide	Results of the Real-Time Water Quality Monitoring will be used: • To determine long term impact of implementing LID in watersh Credit River and Lake Ontario water quality • To determine long term impact of implementing CVC Stormwat document on Credit River and Lake Ontario water quality • To adjust the existing design criteria specified by the CVC Storm Criteria document to address targets established for the Great L

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How Does CVC's SWM Monitoring Program meet Peel Council Priorities?

Goal: Protect, enhance, and restore the environment; Complete, livable, vibrant communities that respect Peel's natural heritage

Actions	Peel Council Priorities Actions	What does the Region of Peel need to implement their priorities?	CVC initiative	What is monitoring doing to facilitate Peel Council Pri
1.1	Demonstrate leadership in responsible environmental management practices and energy use.	• Develop stormwater management framework with area municipalities and conservation authorities • Support implementation of framework recommendations adopted by Council	LID is an innovative stormwater management approach, to minimize the potential adverse physical and chemical impacts of urban runoff by managing runoff. LID Guide: to provide guidance for the implementation of LID features. LID Discussion Paper: identifies the benefits of LID and highlights LID case studies. Also, provides guidance on maintenance, economics, testing the safety factor, and assessing the need for LID Thermal Guide: to provide information on thermal mitigative measures that can be adopted to improve conventional stormwater management practices. Criteria Document: provides guidance in the planning and design of stormwater management infrastructure and outlines the processes and infrastructure needed to address flooding, water quality, erosion and water balance. Construction Guide: guides the proper construction of LID designs, use proper controls and how to inspect, and ultimately, the success of LID throughout Ontario Landscape Guide: provides an understanding of the guiding principles of LID planting design, implementation and management. SWI: demonstrates the benefit of implementing innovative stormwater management practices like LID. This incorporates the planning and implementation of the monitoring at each site. This will improve the knowledge of environmental management practices and enhance the conventional stormwater approaches. Salt Management: to provide source water protection (protection of wells used for water intake) Pollution Prevention: describes the potential sources of pollutants that may wash into the storm sewer system and incorporates strategies of environmental management practices.	LID Guide: monitoring water quality and quantity at all the LID sites w information to the direction regarding landscape-based stormwater m planning and practices. LID Discussion Paper: the LID monitoring provides information on the performance of LID as a source of managing stormwater. This will sup transition from conventional SWM practices to new SWM techniques Thermal Guide: monitoring is measuring temperature levels at up-gra structure, stormwater pond (vegetated floating islands, Peninsulas an outlet structure. This will demonstrate the reduction of thermal impa stormwater management from conventional design. Criteria Document: monitoring of all LID sites will provide feedback in design of SWM features by evaluating the performance. This will dete average performance using innovative technologies and develop desi Construction Guide: monitoring at all LID sites will provide a means in specific construction practices/issues to the performance of a LID pra construction. Landscape Guide: Monitoring staff are evaluating the suitability of pl was used within the bioretention systems at the Public Lands sites. Th includes both the function and suitability of the plants within the cells standards and facilitates the revisions to the Landscaping Guide. Salt Management: CVC staff is monitoring both sodium and chloride l land uses, for example the Mill Creek sub-catchment. This will charact similar land uses and help improve environmental management pract Pollution Prevention: Clear water projects, observation monitoring at Manufacturing, Bernardi Building Supply and Unifay-Fedar Investmen
1.2	Minimize the impact of waste.	• Update long term Waste Management Strategy • Implement long term Waste Management Strategy • Update Water and	Pollution Prevention: Describes the potential sources of pollutants that may wash into the storm sewer system and incorporates strategies of environmental management practices.	Pollution Prevention: Clear water projects, observation monitoring at Manufacturing, Bernardi Building Supply and Unifay-Fedar Investmen

Actions	Peel Council Priorities Actions	What does the Region of Peel need to implement their priorities?	CVC initiative	What is monitoring doing to facilitate Peel Council Pri
				associated with stormwater management from conventional design. Landscape Guide: Evaluating the suitability of plant species that were bioretention systems at the Public Lands sites will include both the fu of the plants which can improve air quality.
1.4	Protect and restore water resources, significant natural heritage and environmentally sensitive areas	• Review water efficiency plan • Implement Water Efficiency Plan	LID promotes a watershed approach to protect sensitive areas. It supports natural land cover and leads to more diverse plants and habitat refuges within developed areas. LID can play a pivotal role in habitat protection and aquatic species biodiversity recovery. In addition, LID will improved water conservation, aquifer recharge and source water quality protection. LID Guide: to provide guidance for the implementation of LID features. LID Discussion Paper: identifies the benefits of LID and highlights LID case studies. Also, provides guidance on maintenance, economics, testing the safety factor, and assessing the need for LID. Thermal Guide: to provide thermal practices that can be adopted to improve conventional stormwater management practices. Landscape Guide: provides an understanding of the guiding principles of LID planting design, implementation and management LID Guide.	LID Guide: Monitoring of all LID sites provides information and directi landscape-based stormwater management planning and low impact d stormwater management practices. LID Discussion Paper: the LID monitoring provides information on the performance of LID as a source of managing stormwater. This will sup transition from conventional SWM practices to new SWM techniques Thermal Guide: Measure temperature at up-gradient, inlet structure, (vegetated floating islands, Peninsulas and pond shape) and Outlet St thermal impacts associated with stormwater management from conv Landscape Guide: Information through the monitoring of plant surviv LID demonstration sites. This can be completed by incorporating nativ species that improve the natural heritage in the community, and spec benefits to rare or at risk species.
1.6	Promote low impact development and urban restoration	• Develop stormwater management framework with area municipalities and conservation authorities • Support implementation of framework recommendations adopted by Council	SWI: demonstrates the benefit of implementing innovative stormwater management practices like LID. This will improved the knowledge of environmental management practices and enhance the conventional stormwater approaches. LID Guide: to provide guidance for the implementation of LID features and promote the use of community living spaces, and enhances outdoor living spaces. LID Discussion Paper: identifies the benefits of LID and highlights LID case studies. Thermal Guide: to provide thermal practices that can be adopted to improve conventional stormwater management practices. Landscape Guide: provides an understanding of the guiding principles of LID planting design, implementation and management LID Guide.	Monitoring water quality and quantity at all the LID sites will prov innovative storm water techniques and contribute to the LID Guide, D Thermal guide and Landscape Guide. Sequentially, promoting the dev stormwater management with area municipalities and conservation a LID Discussion Paper: the LID monitoring provides information o performance of LID as a source of managing stormwater. This w promote the need for transition from conventional SWM practice techniques.
1.7	Collaborate with other levels of government and agencies on	• Implement an advocacy strategy to influence other levels of government • Monitor strategy and revise as appropriate	LID Guide: to provide guidance for the implementation of LID features. LID Discussion Paper: identifies the benefits of LID and highlights LID case studies. Also, provides guidance on maintenance, economics, testing the safety factor, and assessing the need for LID. Thermal Guide: to provide information on thermal mitigative measures that can be adopted to improve conventional stormwater management practices. Criteria Document: provides guidance in the planning and design of stormwater management infrastructure and outlines the processes and infrastructure needed to address flooding, water quality, erosion and water balance. Construction Guide: guides the proper construction of LID designs, use proper controls and how to inspect, and ultimately, the success of LID throughout Ontario Landscape Guide: provides an understanding of the guiding principles of LID planting design, implementation and management.	At all LID demonstration sites, monitoring is collaborating with other and agencies. This will provide feedback and information on the perf stormwater management practices. LID Guide is collaborate with area municipalities and conservation au LID Discussion paper is partners with Ontario Conservation Authoritie Region, Hamilton and Nottawasaga Valley Conservation Authority. Thermal Guide is collaborating with Grand River, Toronto Region and Conservation Authority, Region of Peel, Fisheries and Oceans Canada, Natural Resources and Ontario Ministry of the Environment. Criteria Document in partnership with the Toronto and Region Conse the Region of Peel. Construction Guide is in collaboration with area municipalities, Toron Conservation Authority and Lake Simcoe Conservation Authority.

How does CVCs SWM Monitoring Program meet Municipal priorities?

Municipal Priorities	Municipal Requirements/Needs to fill Priorities	CVC Initiatives	How does monitoring support Municip
Mississauga			
Lead and Encourage Environmentally Responsible Approaches	• Implement water conservation programs	• LID Guide – RWH: Rainwater harvesting can be done in both residential and commercial/industrial settings, making it a very cost effective way to reduce your water usage, and an environmentally sensitive way to reuse water that would otherwise runoff into the storm sewers. The LID Guide provides information on Rainwater Harvesting which can be used as an important resource for anyone interested in implementing a system. • Landscape Guide/Plant Database – Drought Resistant Plants: By planting drought resistant plants in LID features as well as residential areas, the use of water for irrigation will be reduced. As well as a better chance for plant survival in the future, with effects of climate change. This guide will provide information on which plants would be the most appropriate for different situations and help to better guide residents and businesses on water efficient landscape plans.	• LID Guide – RWH: The water quantity and quality monitoring will s municipal water has been replaced and conserv using Rainwater Harvesting. • Landscape Guide/Plant Database – Drought Res Using drought resistant plants can also achieve CVC's monthly inspections of all LID sites will pr existing plant list to better suit the Credit River
	• Develop a Green Development Strategy (GDS): **Pilot Projects** - showcase successfully implemented green development projects in order to encourage developers. These sites can be used to test/modify the GDS before released to wider group. **Provide marketing** to publicize green development through signs, workshops etc.	• LID Guide: Will help to implement more LID features throughout Mississauga as a part of their "Pilot Projects" since information is available on design, implementation, and operation/maintenance. Our data will demonstrate that successful LID practices are beneficial to new developments as well as older developments where retrofits can be made. • Market Research & Marketing Strategy (Tracy's Report): This report was created after a focus group was held in Mississauga to find out single-family homeowner's opinion on Best Management Practices related to stormwater management. It determined that most people would be willing to make changes to their homes in order to be more environmentally sensitive, and adopt better SWM practices residentially.	• LID Guide: All of CVC's LID sites will address the pilot proje GDS. The results from CVC's performance moni water quality, runoff volume reduction etc) will the GDS in showcasing successful implementati • Market Research & Marketing Strategy (Tracy's For proper marketing, CVC's October conferenc development by showcasing successful LID dem will help to promote LID to people already inter guidance on installation and O/M.
Conserve, Enhance and Connect Natural	• Plant one million trees in Mississauga	• Landscape Guide/Plant Database – Drought Resistant Plants: While creating the plant database, drought resistant trees should be identified so they could be used in future LID features to help with Mississauga's goal to plant one million trees.	• Landscape Guide/Plant Database – Drought Res Future tree planting in the LID features can hel their target of 1M. CVC's monitoring staff will p regular basis to monitor performance/survival c
	• Implement a city boulevard beautification program to foster civic pride and raise environmental awareness	• Landscape Guide/Plant Database – Drought Resistant Plants: Mississauga can use this guide and database to select appropriate plants for their boulevards that are drought tolerant, which would increase their success rate and would require less irrigation. This will be very important in the future will the effects of climate change present. • LID Guide: This guide can be used to identify which LID features would work best to take the place of traditional boulevards. It could vary depending on the size and type of surrounding the LID feature will be located in.	• Landscape Guide/Plant Database – Drought Res Since CVC monitoring staff completes a site insp information is constantly becoming available. T identify which plants are the most successful th of LID practices and how we can continue to ma • LID Guide: Monitoring different LID features will provide u determine which feature would be best suited a replacement.
	• Pro-actively acquire and/or enhance land	• Stormwater Management Criteria Document – (Water Quantity/Flooding, Water Quality	• Stormwater Management Criteria Document

Municipal Priorities	Municipal Requirements/Needs to fill Priorities	CVC Initiatives	How does monitoring support Municip
		• <u>Landscape Guide:</u> Enhancements can be made along the waterfront by planting more native species to encourage biodiversity, as well as introducing drought tolerant ornamental plants to beautify the area for both ecological and recreational value. • <u>LOISS – Lake Ontario Integrated Shoreline Strategy:</u> The Lake Ontario Integrated Shoreline Strategy (LOISS) is a multi-year study to analyze the current conditions along the Lake Ontario shoreline. When LOISS is complete, it will provide clear guidance on the steps we need to take as a community to protect and enhance our shoreline ecosystem for the future. This study is the first step in working toward future plans to conserve, enhance and restore shoreline health. This plan will be integrated with broader Lake Ontario, Great Lakes Initiatives, and shoreline plans developed for neighboring coastal areas. • <u>All LID sites:</u> CVC's current LID sites can demonstrate, with the collection of monitoring data, that the water quality is being improved through infiltration and filtration, as well as the reduction in quantity entering traditional stormwater management practices. This allows for a more natural hydrologic cycle to occur in urban areas where infiltration is limited. Baseflow is then recharged to streams and rivers throughout the watershed. This will in turn enhance the land along the waterfront as flooding and erosion will be reduced, and water quality will improve.	quality as TSS will be reduced. • <u>Landscape Guide:</u> Our continued monitoring of plant health withi used to update the guide and database. It will making better place choices. • <u>LOISS – Lake Ontario Integrated Shoreline Strat</u> By collecting water quality samples in different Ontario shoreline we will gain a better underst conditions. This will provide us with a clear dir to be done to protect and enhance the waterfr • <u>All LID sites:</u> Continued monitoring is taking place to collect confirm that LID features are improving the qu stormwater throughout Mississauga.
Promote a Green Culture	• Implement an educational program that promotes "living green."	• <u>Save the Leopard Frog (SLF):</u> This program gets elementary school children involved in their communities by participating in different environmental projects which encourages active learning. Children are being educated from an early age to be "green" so that they are able to develop good habits early.	• <u>Save the Leopard Frog (SLF):</u> Referred to as "SLF Sites", rain garden installati provides an educational program that promote CVC's monitoring program, level loggers are ins infiltration rate, which in turn determines the w detention time. This monitoring is active at a n and styles of LID features. This data will provid understanding of what goes on below the surfa
		Caledon	
Partner with Land Owners and Community to Preserve, Protect and Enhance our Environment and Agricultural Resources and Natural Capital	• Partner with Land Owners to Protect Natural Resources and Agriculture	• <u>LID Guide:</u> Performance monitoring of LID demonstration sites shows improved water quality and reduced runoff volume. This can address the protection of Natural resources within Caledon. Since Caledon relies on groundwater as its main source of drinking water, recharge is very important and LID features can improve this. • <u>Criteria Document:</u> Water quality, quantity, and erosion control will all be addressed in Caledon by installing LID features. Water quality will improve due to infiltration, quantity will increase below ground as infiltration can occur, and erosion will be controlled as stormwater is slowly released back into local waterways.	• <u>LID Guide:</u> Currently in progress, there is a Green Develop Caledon that will implement LID. Performance guidance to this program, as well as informatio features Caledon can implement. • <u>Criteria Document:</u> Water quality, quantity and erosion are all bein sites, so as more data and information become be updated. This will help Caledon select the a depending on the location and needs.

Municipal Priorities	Municipal Requirements/Needs to fill Priorities	CVC Initiatives	How does monitoring support Munici
		accordingly to locate the source of the spill and what it may be.	stations.
	• Conserve and protect the long term ecological function and biodiversity of the natural heritage system. • Promote the accommodation of projected growth while reducing the environmental impact of urbanization through the use of green infrastructure, green development incentives and sustainable best management measures.	• Criteria Document: Water quality, quantity and erosion control are very important in order to protect the long-term ecological function and biodiversity of natural heritage systems. The implementation of more LID features will help to improve these issues and protect the natural heritage system throughout Brampton. • LID Guide: This guide will help to reduce the environmental impact of urbanization through the use of LID features since Brampton is a rapidly developing city. Since more impermeable surfaces are being added, the use of LID will help to offset the negative impacts they have on the local environment. • All LID Sites: Different demonstration sites, especially MITG, will show how new developments are using LID to manage stormwater instead of conventional methods that are damaging to local waterways and our drinking water.	• Criteria Document: Due to increased urbanization and frequent int pollutants sitting on paved surfaces can wash o bodies. LID practices provide treatment and sto these impacts as per the monitoring results. • LID Guide: Monitoring will provide data and information a could best remove pollution as technology cont implement different techniques throughout the • All LID Sites: Since many of our LID sites are different, it is im to see how they react to different environment provide guidance in the future as to which featu to different situations. Long-term monitoring is document any changes that may occur over the feature.
	• Promote development and land use patterns that do not pose a risk to public health and safety in areas that are affected by either human and/or natural hazards.	• Criteria Document: Water quantity is an issues in urban areas where many surfaces are impermeable and do not allow for infiltration. With the increase in larger, more intense events due to climate change, this is becoming more of a concern. The addition of LID throughout urban areas can help with water storage during larger events in order to reduce the risk of flooding. The water will then be filtered slowly through the feature, improving the water quality, and releasing it back into local waterways in a more natural manner.	• Criteria Document: Natural hazards such as flooding are common d now with the threat of climate change. LID mor and water level can determine runoff volume re concern of flooding. Eg: Cooksville's Downspout Disconnection (DD) Pro sewers and prevent residential flooding. CVC partn Peel/Mississauga to implement LID (DD) in pilot sit control sites to show reduction if runoff volume go

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How does CVCs SWM Monitoring Program meet BILD priorities?

BILD Priorities	**BILD Requirements/Needs to fill priorities**	**CVC Initiatives**	How does Monitoring Support CVC Initiat
Shorter development review times Ease of approval process	Simplified navigation of the permit approvals process.	<u>CVC Stormwater Management Criteria DRAFT</u> Plan iterations and re-submissions are reduced as SWMP criteria is presented in a transparent well described document. Development engineers can refer to this document for guidance prior to starting their design and submitting their first application. Clear objectives greatly reduce design iterations as well as the amount of pre-consultation needed with CVC. SWM criteria are standardized throughout the entire watershed which reduces confusion and misinterpretation which often accompanies location specific criteria such as special considerations at the sub-watershed level. Reasoning for the criteria is also provided which helps reduce misunderstandings surrounding SWMP objectives and their importance. Reduced review iterations through efficient communication lowers costs of approvals. <u>LID Stormwater Management Planning and Design Guideline</u> Assists design engineers and avoids unnecessary costs to developers due to re-submissions. SWM criterion varies greatly across Ontario. Acceptable stormwater technology and engineering practices also vary amongst review agencies such as CAs, municipalities, the MOE, and the MTO. SWM design engineers may have confidence proposing LID technologies within the CVC watershed and practicing the design principals outlined in the guide knowing that the techniques are supported by CVC review staff. Also, accountability is of paramount importance to review staff from all agencies. It is expected that review decisions and requests for information be founded and supported by accepted sources of information. The design guideline serves this purpose as a common ground for reviewers and design engineers. The design principals supported by the guide must be tested. Reduced design iterations lowers costs of approvals. <u>CVC Demonstration Project Case Studies</u> Acceptance of LID practices is encouraged for all review agencies and design engineers by highlighting successful projects and identifying past project challenges such as monitoring. A common understanding of LID is established amongst applicants and reviewers. Reduced approvals correspondence lowers costs of gaining approvals.	<u>CVC Stormwater Management Criteria DRAFT</u> The use of LID technology is a key for SWM plans to meet CVC's criteria. There are many perceived barri of LID and the monitoring program helps demonstra barriers can be overcome by testing design principal <u>LID Stormwater Management Planning and Design G</u> The LID monitoring program helps verify, refine and the guidance presented in the guide. The performan features that were designed using the guide are eva either verify or refine the design practices discussed guide. <u>CVC Demonstration Project Case Studies</u> Monitoring is highlighted for the CVC LID projects su Drive, Lakeview, IMAX and others. Each site describ situation. CVC's hands-on experience is valuable to agencies/companies seeking advice regarding sounc practices.
Proof of Concept Economic advantages of design philosophy	Rules of thumb/generalizations of LID vs. BMP comparison (space requirements, grading requirements, costs, approval difficulty)	<u>Discussion Paper</u> The on-the-ground costs saving concepts of LID are discussed. How and where savings can be realized using an LID approach is identified from the perspective of the development as a whole. For example LID may eliminate the need for a SWM pond thereby freeing up space for an additional lot. <u>LID Demonstration Projects</u> A multitude of barriers are being addressed and overcome with the pilot projects. Real world examples of successful projects help build confidence in LID demonstrating that perceived barriers have been overcome. <u>Case Studies of LID Projects Within Ontario</u> Discussing the benefits and cons of a large number of projects leads to generalizations which may be called upon during the concept stage of site plan design. For example if it has been demonstrated that implementing LID at a subdivision led to less site grading and more lots with higher value (due to landscaped use of LID) then a developer may wish to investigate the concept early in the design process.	<u>Discussion Paper</u> The monitoring program helps to validate these con measuring the performance of LID in a treatment tra configuration. The reduced need for conventional B be quantified. <u>LID Pilot Projects</u> Monitoring the storm water performance for these one component towards building confidence in thes <u>Case Studies of LID Projects Within Ontario</u> Monitoring is not a component of this initiative
Advisory Role to	Recognize the value of	BILD may recognize Conservation Authorities value towards managing watercourses, but it may not always	

How Does CVC's SWM Monitoring Program meet CVC's Strategic Plan?

CVC Strategic Plan Priorities	What does CVC need to implement the priorities?	CVC Initiatives	What is monitoring doing to fac
Climate Change	• Innovative mitigation and adaptation techniques • Increase scientific expertise to develop and implement strategies through monitoring and other activities	• LID demonstration sites for mitigation of potential increase in frequency/intensity/duration of storm events as well as water temperature impacts with increasing temperatures • Modeling of LID features to predict impacts of different sized rain events • Real-time water quality monitoring stations provide real-time water quality information including water temperature and level to contribute to a long-term data set • LID Guide to provide guidance for the implementation of LID features • Thermal Guide: to provide information on thermal mitigative measures for stormwater impacts • Criteria Document: provides guidance in the planning and design of stormwater management infrastructure and outlines the processes and infrastructure needed to address flooding, water quality, erosion and water balance. • Construction Guide: guides the proper construction of LID designs, use proper controls and how to inspect, and ultimately, the success of LID throughout Ontario. • SWI: Monitoring the SWI sites provides knowledge to better protect, enhance, and restore the environment. • LID Discussion Paper: gives guide on maintenance, economics, testing the safety factor, and assessing the need for ponds.	• Monitoring of all sites provides informatio based stormwater management planning a stormwater management practices to assis adaptation of climate change • Monitoring real-time water quality provide increase scientific expertise to allow for th Climate change. • Thermal Guide: monitoring of different LID on mitigative measures for end-of pipe tre Floating Islands, Real Time WQ, Meadows IMAX. • Criteria Document: Monitoring at IMAX, El Walnut Grove, Public Lands Sites and CVC the criteria document and planning and de • Construction Guide: monitoring at all LID d guidance of site construction, inspections a effectiveness of LID features
Drought and flooding	• Climate change mitigation and adaptation techniques • Monitoring and increasing scientific knowledge base	• LID demonstration sites (flooding) and reduction in peak flow impacts • Real-time water quality monitoring provide real-time water quality information including water level • LID Guide: to provide guidance for the implementation of LID features • Criteria Document: provides guidance in the planning and design of stormwater management infrastructure and outlines the processes and infrastructure needed to address flooding, water quality, erosion and water balance.	• Monitoring of all sites provides informatio based stormwater management planning a stormwater management practices to assis adaptation of flood impacts • Monitoring real-time water quality provide increase scientific expertise to allow for th mitigation strategies • Criteria Document: Monitoring at IMAX, El Walnut Grove, Public Lands Sites and CVC the criteria document and planning and de
Lack of adequate development standards	• Improved planning and regulation • Land management and conservation areas	• LID Guide: to provide guidance for the implementation of LID features to improve development standards • Criteria Document: provides guidance in the planning and design of stormwater management infrastructure and outlines the processes and infrastructure needed to address flooding, water quality, erosion and water balance. • Construction Guide: guides the proper construction of LID designs, use proper controls and how to inspect, and ultimately, the success of LID throughout Ontario. • Landscape Guide: Assessing aesthetics, public uptake, what works and doesn't work. Such as Public Lands, Elm, Lakeview, Alton and all LID sites in S. Ontario.	• Monitoring of all sites provides informatio based stormwater management planning a stormwater management practices • Monitoring of all LID demonstration sites p and insights for the improvement of LID im maintenance, and landscaping, to ultimate standards
Deteriorating urban environment	• Protection and restoration of watershed health through shared priorities • Watershed restoration activities • Monitoring • Water quality strategy	• LID demonstration sites- improvements in pre-existing urban areas using LID as well as new construction • LID Guide: to provide guidance for the implementation of LID features • Landscape Guide: Assessing aesthetics, public uptake, what works and doesn't work. • Construction Guide: guides the proper construction of LID designs, use proper controls and how	• Monitoring of all sites provides informatio based stormwater management planning a stormwater management practices • Landscape Guide: monitoring of LID demo Elm, Lakeview, Alton etc) for functionality

CVC Strategic Plan Priorities	What does CVC need to implement the priorities?	CVC Initiatives	What is monitoring doing to fac
	areas • Education and partnerships • Water management implementation • Monitoring • Water quality strategy	• Real-time water quality stations throughout watershed • Criteria Document: provides guidance in the planning and design of stormwater management infrastructure and outlines the processes and infrastructure needed to address flooding, water quality, erosion and water balance. • LID Guide: to provide guidance for the implementation of LID features	and erosion control • Criteria Document: Monitoring at IMAX, E Walnut Grove, and CVC Head Office provic document and planning and design of SWN • Monitoring real-time water quality provide stream sediment loading following rain eve
Water supply	• Water management implementation • Education • Planning and regulation • Water quality strategy • Lake Ontario	• CVC rain water harvesting system • Rain water gardens • Lake Ontario Integrated Shoreline Study	• All LID demonstration sites- monitoring of with the implementation of LID features. E scale improvements to water quality to pro • Monitoring of the Lake Ontario Shoreline w knowledge base for the protection of our v
Neighborhood and development pressures	• Natural heritage protection • Planning and regulation • Protection and highlighting natural heritage • Education • Partnerships	• Landscape Guide: Assessing aesthetics, public uptake, what works and doesn't work. Such as Public Lands, Elm, Lakeview, Alton and all LID sites in S. Ontario. • LID demonstration sites incorporating natural heritage features and landscaping using native species • Criteria Document: provides guidance in the planning and design of stormwater management infrastructure and outlines the processes and infrastructure needed to address flooding, water quality, erosion and water balance. • LID Guide: to provide guidance for the implementation of LID features	• Monitoring of all demonstration sites to pr storm water techniques • Landscape Guide, Criteria Document and L further insights for these documents to pro information to promote LID and improve d
Species at Risk	• Natural heritage protection • Land management and conservation areas • Education • Partnerships • Watershed restoration • Water quality strategy • Lake Ontario	• Thermal mitigation measures (temp and TSS);runoff reduction • Real-time water quality monitoring stations provide real-time water quality information including water temperature and level to contribute to a long-term data set • Floating Islands, all LID demonstration sites • Coldwater fisheries- Redside Dace and coldwater species protection • Thermal Guide: to provide information on thermal mitigative measures for stormwater impacts • SWI: Monitoring the SWI sites provides knowledge to better protect, enhance, and restore the environment. • Landscape Guide: Assessing aesthetics, public uptake, what works and doesn't work. Such as Public Lands, Elm, Lakeview, Alton and all LID sites in S. Ontario.	• Monitoring real-time water quality provide increase scientific expertise to allow for th mitigation strategies • Thermal Guide: Monitoring at LID sites tha measures (Floating Islands) will provide ins these measures and potential future impro • SWI: Monitoring the SWI sites provides kno enhance, and restore the environment usi • Landscape Guide: Informed through the m fecundity at LID demonstration sites; incor species, species that improve the natural h species that provide benefits to rare or at r
Soil quality and quantity	• Monitoring • Waste reduction • Water management implementation • Water quality strategy	• LID demonstration sites incorporating infiltration and possible treatment approaches (IMAX) • LID Guide: to provide guidance for the implementation of LID features	• LID Guide: monitoring at all demonstration implementation of LID features to examine and erosion control • Soil quality monitoring to determine soil qu of water and soil following infiltration thro

Reference:

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How Does CVCs SWM Monitoring Program fit within CVC's SWM Initiatives?

CVC Initiatives	Monitoring Programs, Sites & Activities	What is Monitoring doing at/with these Programs, Sites & Activities to Inform, Support & Build Upon CVC Initiatives?
LID Design Guide	• All Sites	Monitoring at the various LID sites have provided valuable data and lessons learned that have led to the development (and updating) of several CVC initia Design Guide. For instance: • Post-construction visual inspections at Green Glade Sr. Public School and Portico Church detected poor performance of the bioretention soil media. Co and testing revealed that the soil media installed did not meet design specifications. These monitoring activities led to the ongoing refinement of the b specification and need to emphasize the importance of meeting the specification in order to minimize future issues. • Quality & Quantity data collected at sites like Elm Drive and others shall also be used to help refine the sizing guidelines provided in the LID Design Guid • Effective pre-treatment strategies are also being examined by monitoring staff at Public Lands sites. Sediment accumulation prior to/at the LID practice monitored. These observations are being recorded to determine the needed cleanout frequencies, as well as the best means of pre-treating stormwate LID practice (such as vegetated pretreatment, OGS or other type of filter, forebay, or other approach). Supporting LID SWM Monitoring Strategy Goals: 1, 2, 5, 7, 8, 10, 11, 12, 13, 14, 16 (numbering key can be found at end of table)
Construction Guide	• Construction inspection of Elm, Lakeview and Portico • Mount Pleasant • Lakeside Park • Green Glades • CVC Office • Public Lands Sites • Imax • P2 Sites	CVC staff routinely go on-site during the construction of LID practices in our watershed. This construction monitoring provides CVC with in-depth knowle encountered (and successes achieved) by engineers, contractors and city staff when implementing LID projects. Construction monitoring has taken place including Elm Drive, Lakeview, Portico Church, CVC head office and others. This experience has led to the creation of the Construction Guide which addre during monitoring, including: protection of infiltration areas during construction, construction sequencing, etc. Monitoring work is also supporting the refinement of the Construction Guide by providing a means in which to correlate specific construction practices/is of a LID practice post-construction. By combining construction inspection and performance data, CVC can identify the practices/issues that have the grea impacts to the future performance of LID practices. This crucial information can then be used to develop and refine protocols in future editions of the Co best target the items that have the greatest impact on performance. Supporting LID SWM Monitoring Strategy Goals: 2, 3 (numbering key can be found at end of table)
Landscape Guide	• Public Lands • Elm • Lakeview • Alton • All LID sites	Following the completion of several pilot projects, such as Elm Drive and Portico Church, it has become evident that the current edition of the Landscape to ensure that LID practices are better integrated within urban environments and that they can be easily maintained. To facilitate these revisions to the L monitoring staff are evaluating the suitability of plant species that were used within the bioretention systems at the Public Lands sites. This evaluation in and suitability of the plants within the cells as well as aesthetic standards. Monitoring efforts are supporting these evaluations by conducting recurring plant coverage surveys at the Public Lands and Elm Drive sties. Additional m feed into theses surveys include the collection of data on factors affecting plant health, such as ambient temperature, rainfall, volume of water retained i cell drawdown time. Supporting LID SWM Monitoring Strategy Goals: 4, 15 (numbering key can be found at end of table)
Thermal Guide	• Floating Islands • Elm • Lakeview • Real Time WQ • Meadows in the Glen • Walnut Grove • IMAX • IWMP • Fletcher's Creek EM	The Thermal Guide provides thermal mitigation practices that can be adopted to improve conventional stormwater management practices. Monitoring s Guide through the collection of temperature data at a variety of different sites and locations. One of the major monitoring efforts includes the monitorin 10 – the floating islands. This project is aimed at validating the use of floating islands to reduce heat gain in wet ponds by collecting data at pond inlet, ou the floating islands. Temperature data is also being collected in-stream in the CVC watershed. This data helped identify that current SWM approaches are not working, and th measures, and more importantly, practices that do not increase runoff temperature (and cool stormwater) are needed to improve the health of CVC's wa Supporting LID SWM Monitoring Strategy Goals: 9 (numbering key can be found at end of table)

SWM Criteria Document	• IMAX • Elm Drive • Meadows in the Glen • Walnut Grove • Public Lands Sites • CVC Head Office • In-stream monitoring	The multi-year performance evaluation of the LID sites will be used: • To determine long term average performance of the innovative technologies • To develop design criteria and guidelines for the innovative technologies • To adjust the existing design criteria for end-of-pipe facilities when LID is implemented in site level • To adjust existing SWM design criteria in Light of Climate Change i.e. changing of rain fall patterns, temperature and flooding • To develop technical assessment tools for approval process where LID is proposed Supporting LID SWM Monitoring Strategy Goals: 1, 2, 5, 6, 10, 11, 12, 13, 14, 16 (numbering key can be found at end of table)
LID Retrofit Guidelines	• SWI Monitoring Sites • Case Studies • Public Lands Sites • Elm • Lakeview • IMAX	Monitoring is an integral component of the SWI project. The quantitative and qualitative data gathered will be incorporated into the Retrofit Guidelines be the project as a means of demonstrating the benefits of retrofitting with LID. The planning and implementation of monitoring at the sites shall also be disc case studies. Elm Drive monitoring data shall be used to verify if the LID practices are performing as expected (in accordance with that modeled in the original design). If performance differs from the projected performance, then monitoring data can be used to make suggestions on improving design calculations. Monitoring provide critical information on how LID retrofits in existing neighborhoods built before current SWM standards can be implemented and the benefits to SW quality that can be achieved from these retrofits. Monitoring at the CVC head office involves parking lot permeable pavers and enhanced swales along with rooftop rain harvesting. Although these enhance described as a re-development rather than a retrofit, lessons learned may apply to the retrofit guide and communicated through case studies. Observed pe compared to that expected to verify and refine design principals to be referred to in the design guideline. With the Public Lands sites, monitoring data shall be used to support the development and refinement of adoption protocols for landowners or O&M perso management of LID practices following the completion of construction and/or warranty periods. Older LID sites, such as Riverwood, shall provide an oppor contaminant accumulation in the swales plants and soil and better understand issues surrounding maintenance. Finally, an extensive monitoring program is being conducted at IMAX. This monitoring program will compare a control catchment (asphalt) to permeable p examine the performance of innovative SW treatment products by Imbrium (Jellyfish and sportive media) on stormwater quality. The data collected will pr information on how to retrofit typical commercial parking lots with LID features. The data will also help to quantify the potential benefits to municipalities across multiple lots. Supporting LID SWM Monitoring Strategy Goals: 3 (numbering key can be found at end of table)
LID Discussion Paper	• Public land sites • Elm • Walnut Grove • Meadows in the Glen • Instream monitoring	Monitoring work supports the LID Discussion Paper by providing data that supports the need to transition from conventional SWM practices (which are not the intended benefits) to new SWM techniques which include LID. For instance instream monitoring observed an increase in flows in an urbanizing sub-wa the presence of conventional stormwater controls. Supporting LID SWM Monitoring Strategy Goals: 1, 4, 6, 7, 8, 10, 11 (numbering key can be found at end of table)

Salt Management	• CVC Office sites • Orangeville • Mississauga • GO Transit • IMAX	CVC monitoring staff routinely collects water samples to determine salt loading and demonstrate how LID practices (ie permeable pavement, impermeable reduce the need for salting during winter. The overall purpose for salt management is to provide source water protection (protection of wells used for wat Orangeville, Alton etc).The valuable monitoring data will be reflected in their respective case studies to show salt management through LID. Supporting LID SWM Monitoring Strategy Goals: 7 (numbering key can be found at end of table)
IC P2	• Bernardi • Unifay-Fedar • Orangeville	CVC's role in the projects included construction inspection and post-construction monitoring. During the construction phase, CVC monitored and photogra ensure successful implementation of P2 strategies. In post-construction monitoring, site visits were carried out on a monthly basis to ensure that all of the functioning as intended and address any of the landowner's questions or concerns. If any problems were found, they were dealt with immediately by infor landowner and contractor. If required, the contractor could be called in to assess any changes in site conditions, complete warranty work and explain any a needed to prevent the issues to the landowner. Photo logs were completed during these site visits which were compared to previous conditions and any ch noted. Due to site constraints, no water quality or quantity data is collected at these sites. Logged notes and photographs during pre-construction, constru construction phases were assembled into a case study which documents the planning, design, construction and maintenance phases of the pollution preve demonstration sites. Supporting LID SWM Monitoring Strategy Goals: 6, 7, 14 (numbering key can be found at end of table)
Case Studies	• CVC head office • Elm Drive • IMAX • Lakeview	Case studies provide a means to showcase sites that have implemented LID, and highlight successes and discuss issues/barriers faced and how they were o performance monitoring data being collected at a variety of sites, including CVC head office, Elm Drive, IMAX and others will be incorporated as an importa within the case studies. This data will be used to communicate the benefits of LID at in-the-ground sites in the GTA. This data will help to promote the ado Ontario by demonstrating that these practices perform well in Canadian cold weather conditions. Monitoring case studies are also being developed to provide our stakeholders with information on how to plan and implement LID monitoring projects. CV experience in this emerging field, and by sharing this experience, CVC shall be able to position itself as a recognized expert in this field and to ensure that o are able to conduct LID monitoring projects more effectively. Supporting LID SWM Monitoring Strategy Goals: 3, 4, 8, 13, 15 (numbering key can be found at end of table)
Water Management Strategy		The multi-year performance monitoring of the LID sites provides insights into how to implement LID projects successfully. This data shall help to promote t adoption of LID. The impacts of development on CVC watercourses are expected to be minimized with widespread adoption of LID stormwater manageme Monitoring results will be used to characterize watershed conditions and to provide feedback on management decisions. Continuous monitoring allows de test assumptions made during the study and to assess how well management solutions are working. The results from monitoring are then used to update a management solutions over time (Credit River Water Management Strategy Update, April 2007) Supporting LID SWM Monitoring Strategy Goals: 2, 4, 5, 9, 10, 11, 16 (numbering key can be found at end of table)

LID SWM Monitoring Goals, Table 5, *Stormwater Management Monitoring Strategy Report*

1. Evaluate how stormwater management ponds perform with LID upstream. Can the wet pond component be reduced or eliminated by meeting the erosion and water quality objectives with LID?
2. Evaluate whether LID SWM systems are providing flood control, erosion control, water quality, recharge, and natural heritage protection as per the design standard.
3. Evaluate and refine construction methods and practices for LID projects.
4. Evaluate long-term maintenance needs and maintenance programs, and the impact of maintenance on performance.
5. Evaluate effectiveness of soil amendments and increased topsoil depth for water balance and long-term reliability.
6. Assess the potential for groundwater contamination in the short and long term.
7. Assess the performance of LID designs in reducing pollutants that are dissolved or not associated with suspended solids (i.e. nutrients, oils/grease, and bacteria)
8. Determine the life cycle costs for LID practices
9. Demonstrate the degree to which LID mitigates urban thermal impacts on receiving waters
10. Assess the water quality and quantity performance of LID designs in clay or low infiltration soils and those that do not use infiltration.
11. Assess the water quality and quantity performance of LID technologies
12. Evaluate how a site with multiple LID practices treats stormwater runoff and manages stormwater quantity as a whole.

Identify new questions CVC and Peel would want to learn from our monitoring to meet Strategic Plan and Peel priorities

No.	*Questions*	*Aligns wi*
1	At what scale must LID practices be implemented to make a significant impact on addressing SWM issues across the watershed?	• Peel (Climate Change Str • Municipalities
2	How effective are LID practices in light of climate change? i.e., Can LID be used to reduce the risk of flooding from high-intensity, short-duration rainfall events? How must LID practices be sized to facilitate climate change adaptation?	• Peel • Municipalities • IBC • BILD
3	How can LID be effectively implemented within municipal standards?	• Municipalities
4	How can LID support urban tree growth?	• Peel (Climate Change Str • Municipalities
5	What are the life cycle characteristics of LID practices? How frequently will they need regular maintenance (weeding, plant replacement, etc.) and how frequently must they be remediated to restore function to the practice? How do construction practices like sediment control impact the performance of LID?	• Municipalities
6	What are the long-term effects on groundwater from LID?	• Municipalities
7	What is the expected performance of LID features for reducing stormwater runoff from ICI properties, particularly with respect to the potential for stormwater rates? What proportion of stormwater rates should be rebated if LID practices are implemented? What level of enforcement is necessary to ensure that LIDs are functioning as intended to maintain a rebate?	• Municipalities
8	How can pre-assembled LID modules (tree boxes, Filterra) be used to streamline LID retrofits and new builds in municipal ROWs?	• Municipalities
9	How can LID reduce the cost of maintaining existing SWM ponds? Can it be used as pre-treatment to reduce sediment accumulation (and pond clean-out frequency)?	• Municipalities
10	Are LID practices an effective means of minimizing pollutant loading to Lake Ontario? And if so, does pollutant reduction ease the complexity and cost of treating water for Peel's water supply system?	• Peel
11	What is the best way to maintain LID features. CVC experience may lend itself to a maintenance guide describing planting/weeding schedules. This would be useful to anyone responsible for the upkeep of LID features.	• Municipalities

How do we communicate these Monitoring Results to our Partners?

1. Participation in technical/advisory committees (i.e., present at Peel climate change meetings, green economy meetings, LID review facilitation group, etc.)
2. Presentation at conferences hosted by CVC and other partners
3. Discuss monitoring issues, barriers, solutions and lessons learned through in-depth case studies and brief fact sheets
4. How-to/educational videos posted to CVC website (i.e., featuring Sean James discussing how to maintain a rain garden)
5. Incorporate monitoring experimental design recommendations and performance monitoring findings into SWI retrofit guidelines

Contributions/comments to the creation of new technical documents/guidelines and/or revisions to exis

APPENDIX B:

CVC SWM Monitoring Plan Factsheets:

Meadows in the Glen - Residential Development
Elm Drive - Road Retrofit
Lakeview District Neighbourhood - Road Retrofit
Riverwood Conservancy - Parking Lot Bioswale
CVC Building - Green Office Building
Floating Treatment Wetlands - SWM Pond Thermal Mitigation
Pond 10 Monitoring - SWM Pond Monitoring
Orangeville Winter Road Salt Study

APPENDIX B-1 MEADOWS IN THE GLEN – RESIDENTIAL DEVELOPMENT

Meadows in the Glen is a subdivision of estate homes located in the Hamlet of Glen Williams in the Town of Halton Hills. The Meadows in the Glen project is the first greenfield Low Impact Development subdivision in the Credit River Watershed. The planned design for the Meadows in the Glen subdivision includes LID measures such as narrower road widths, porous pavement, street swales, rain gardens, bioretention, soakaway pits, preservation of woodlands, and water and energy conservation measures. CVC will be monitoring this site to ensure that the LID practices put in place function as designed. Groundwater monitoring started in January 2010, other monitoring will start once construction is finished and the site has stabilized. The full monitoring plan for this project can be found in Appendix B.

LID Practices Implemented

Residential lots:

- Roof soakaway pits
- Rain gardens
- Permeable Pavement Driveways

Road allowance:

- Swale drainage
- Biofilters

Figure 1 Meadows in the Glen Development Site Plan

Why is this Project Being Monitored?

- CVC is evaluating the effectiveness of the various LID measures as a whole in reducing stormwater runoff, improving the quality of the stormwater runoff, and maintaining groundwater infiltration.
- CVC will also conduct a water balance on one of the stormwater ponds to determine if pond sizes can be reduced in developments that incorporate LID.

What is being monitored?

- CVC is currently measuring the groundwater level in six wells located thought the site with continuous water level loggers and taking groundwater samples twice per year.
- Once the development is complete, CVC will start measuring the water flow entering Stormwater Pond A and the flow exiting stormwater pond A and B using continuous level loggers and weirs. Flow weighted water samples will also be taken during precipitation events at these locations. In addition, water flow will be measured and

geomorphological monitoring will be conducted along the small tributary to which Stormwater Pond A drains.

When did monitoring begin?

- Groundwater monitoring started in January 2011.
- The remainder of the monitoring program will start once construction is finished and the site has had time to stabilize.

Who are the Partners?

- Credit Valley Conservation, Intracorp Canada, the Town of Halton Hills, Environment Canada, and the Ontario Ministry of the Environment.

APPENDIX B-2 ELM DRIVE - ROAD RETROFIT

The Peel District School Board has partnered with the City of Mississauga and Credit Valley Conservation (CVC) to develop a “Green Street” pilot project for Elm Drive located approximate two blocks south of Square One in Mississauga. More recently, increases in the frequency of severe rain events has increased concern over urban flooding. Cooksville Creek, an urban Mississauga stream, flooded its banks back in August 2009. To help address rising concern over urban flooding the Elm Drive pilot project will incorporate green features such permeable pavement and bioretention planters that will filter and store water washing off roads and parking lots before entering Cooksville Creek and Lake Ontario.

LID Practices Implemented

- Bioretention planters
- Permeable Paving Stone Parking Lay-bys

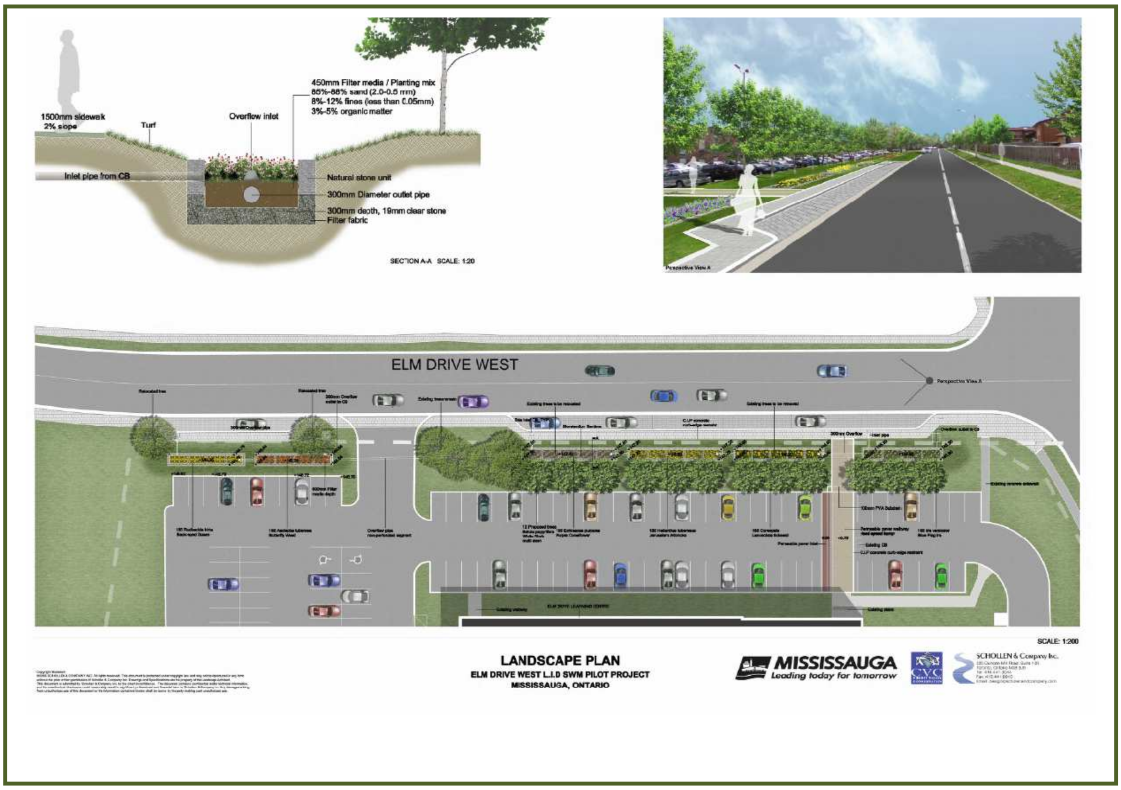

Figure 2 Elm Drive Retrofit Plan

Why is this project being monitored?

- CVC is evaluating the effectiveness of the bioretention planters and permeable pavement at reducing the volume and improving the quality of stormwater runoff from the neighbourhood roads compared to roads with conventional curb and gutter design.

What is being monitoring?

- CVC is measuring water flow using a continuous level logger and a weir.
- In future years, flow weighted water samples will also be taken during precipitation events.

When did monitoring begin?

- Water flow monitoring will began in July 2011.
- Water quality sampling will begin in 2012.

Who are the Partners?

- Credit Valley Conservation, the City of Mississauga, the Peel District School Board and the Ontario Ministry of the Environment.

APPENDIX B-3 LAKEVIEW DISTRICT NEIGHBOURHOOD - ROAD RETROFIT

City of Mississauga and Credit Valley Conservation (CVC) have partnered to develop a "Green Street" pilot project for two streets in the Lakeview District Neighbourhood located in southwest Mississauga. This area of Mississauga is one of the few that still has swales for drainage as opposed to curb and gutter. Instead of following standard practice and converting the streets in the neighbourhood to curb and gutter, Mississauga has decided to construct enhanced roadside swales. The road redevelopment includes enhanced swales that will help reduce stormwater runoff and improve water quality discharging into storm sewers and eventually into Lake Ontario.

LID Practices Implemented

- Permeable Paving Stone Driveways and Parking Lay-bys
- Enhanced Roadside Swales

Figure 3 Elm Drive Retrofit Plan

Why is this project being monitored?

- CVC is evaluating the effectiveness of the enhance swales and permeable pavement at reducing the volume and improving the quality of stormwater runoff from the neighbourhood roads compared to roads with conventional curb and gutter design.

What is being monitored?

- Water flow using continuous level loggers and weirs.
- Flow weighted water samples will be taken during precipitation events.

When did monitoring begin?

- The collection of preconstruction background data started in July 2010
- Once construction has started monitoring will stop until construction is finish and the site has stabilized. Monitoring will likely begin again in fall 2013.

Who are the Partners?

- Credit Valley Conservation, the City of Mississauga, and the Ontario Ministry of the Environment.

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APPENDIX B-4 RIVERWOOD CONSERVANCY – PARKING LOT BIOSWALE

The Riverwood Conservancy (TRC) is located in central Mississauga along the Credit River. The stormwater drainage for the main parking lot of TRC is served by a combination of catch basins with internal storm sewers, and a bioswale, which drain directly to a wetland pond. The parking lot drainage sheet flows to a central bioswale. The swale was installed to reduce the quantity and improve the quality of stormwater runoff from the parking lot to the Riverwood Wetland, MacEwan Creek, and ultimately the Credit River.

LID Practices Implemented

- Parking Lot Bioswales

Figure 4 Riverwood Bioswale

Why is this project being monitored?

- CVC is evaluating the effectiveness of the bioswale at reducing the volume and improving the quality of stormwater runoff from the parking lot compared to conventional parking lots.

What is being monitored?

- Water flow using a continuous area velocity flow meter.
- Flow weighted water samples are also being taken during precipitation events.

When did monitoring begin?

- Monitoring started in June 2010

Who are the Partners?

- Credit Valley Conservation, the City of Mississauga, the Riverwood Conservancy and the Ontario Ministry of the Environment.

APPENDIX B-5 CVC BUILDING - GREEN OFFICE BUILDING

To show CVC’s commitment to the environment, the design of the New CVC Head Office Building, located along the Credit River in Mississauga, includes various low impact development (LID) methods. The building includes LID measures such as, a rainwater harvesting system, a permeable pavement parking lot with perimeter bioswales, and water and energy conservation measures. These methods will help to reduce the buildings environmental impact. The building is on track to reach a LEEDS gold level.

LID Practices Implemented

- Permeable Paving Stone Parking Lot
- Perimeter Bioswales
- Rainwater Harvesting Systems

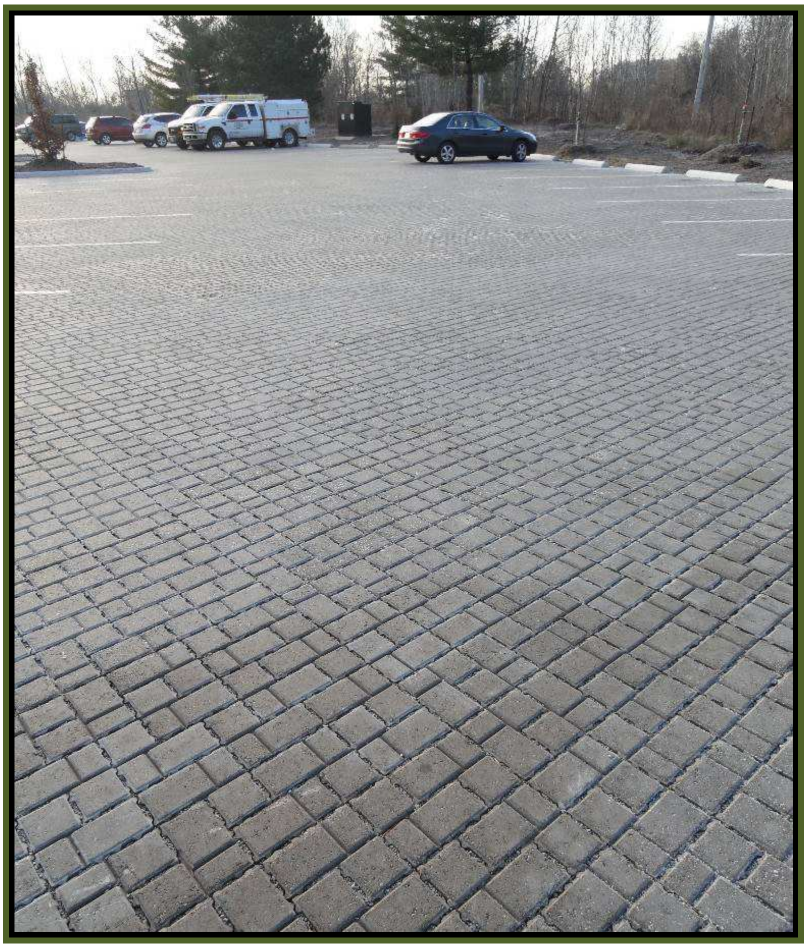

Figure 5 Permeable Pavement in Parking Lot at CVC Office

Why is this project being monitored?

- CVC is evaluating the effectiveness of the swales and permeable pavement at reducing the volume and improving the quality of stormwater runoff from parking lot.
- A water balance is also being conducted on the rainwater harvesting system to determine the cost savings over using municipal water.

What are we monitoring?

- In the parking lot, CVC is measuring water flow from the parking lot using a continuous level logger and a weir. Flow weighted water samples are also being taken during precipitation events.
- For the Rainwater Harvesting System, CVC uses continuous flow loggers to measure the water flow entering and exiting the rainwater harvesting tank. Grab water quality samples are also being taken from the rainwater tank.

When did monitoring begin?

- Monitoring will begin when the parking lot is assumed

Who are the Partners?

- Credit Valley Conservation and the Ontario Ministry of the Environment.

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APPENDIX B-6 FLOATING TREATMENT WETLANDS – SWM POND THERMAL MITIGATION

Urban stormwater ponds have become a widely utilized method for the treatment of stormwater in the newer areas of the Credit Valley Watershed to prevent erosion and the transport of sediments to receiving watercourses. Although quite effective for the purposes of removal of coarse particles, these ponds are typically less effective at removing fine suspended particulates and nutrients. In addition, building ponds on cold water systems can lead to a dramatic increase in water temperature in receiving streams that often provide habitat for sensitive species such as brook trout and redside dace. To help reduce these impacts vegetated Floating Islands have been installed in a stormwater pond known as Pond 10 in the Fletcher's Creek Subwatershed in Brampton and islands are proposed for Jannock Pond in Mississauga. Floating treatment wetlands grow wetland plants (hydroponically) on a mat that is floated on the pond's surface. They are intended to enhance the treatment effect of conventional stormwater ponds by reducing the nutrient levels and the temperature of water discharging from the pond to receiving streams.

LID Practices Implemented

- Floating Treatment Wetlands

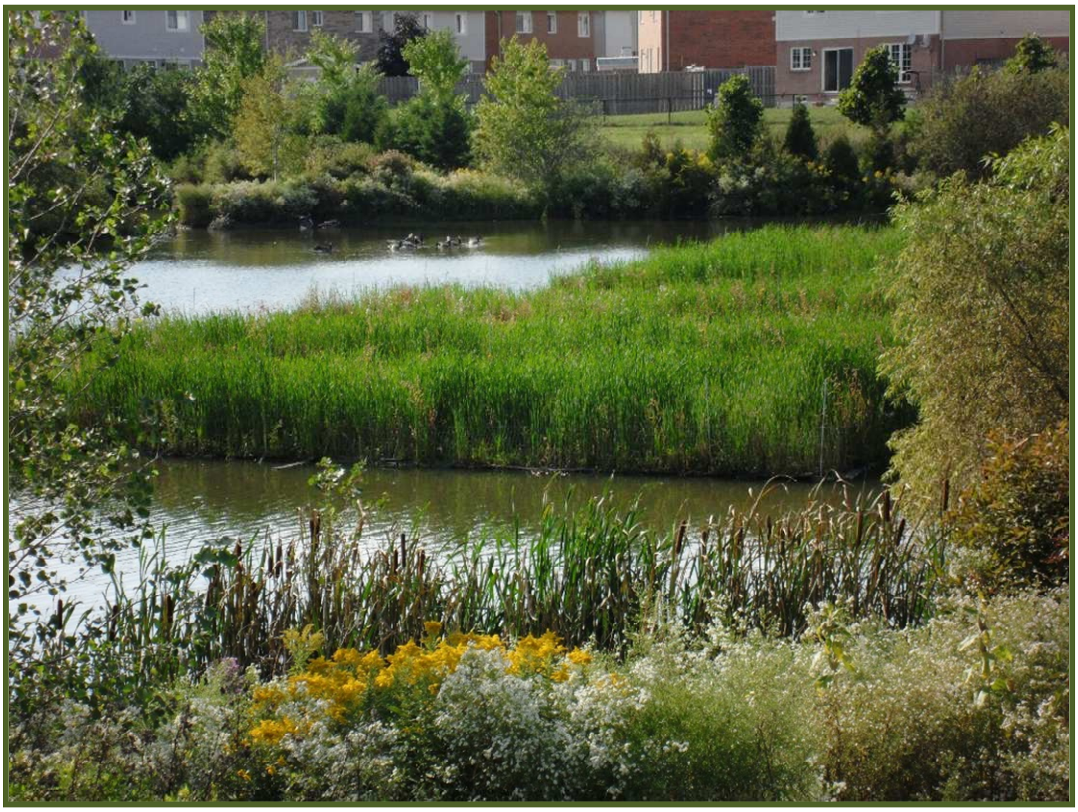

Figure 6 Floating Treatment Wetland in Pond 10, Brampton

Why is this project being monitored?

- CVC is evaluating the effectiveness of Vegetated Floating Treatment Wetlands in reducing the temperature of the water discharging from the pond to Fetcher's Creek.
- In future years, CVC will also look at the nutrient reduction capabilities of the floating wetlands.

What is being monitored?

- Water temperature from June 1 to September 30 at the inlets and outlets, and throughout the pond.
- In future years, CVC will also monitor water flow and water quality entering and exiting the pond.

When did monitoring begin?

- Temperature monitoring and grab water quality samples at the inlets and outlet started in 2005 as part of CVC's Effectiveness Monitoring Program
- Temperature monitoring throughout the pond started July 2010

Who are the Partners?

- Credit Valley Conservation, the City of Brampton, C&M Aquatics, Greenland International Consulting Limited and Fletcher's Meadow Secondary School.

APPENDIX B-7 POND 10 MONITORING – SWM POND MONITORING

Urban stormwater ponds have become widely used in more recently developed parts of the Credit Valley Watershed to prevent erosion and the transport of sediments to receiving watercourses. Although quite effective at the removal of coarse particles, these ponds are typically less effective at removing fine suspended particulates and nutrients. In addition, building ponds on cold water systems can lead to a dramatic increase in water temperature in receiving streams that often provide habitat for sensitive species such as Brook Trout and Redside Dace. To verify these impacts CVC has been collecting monitoring data in a stormwater pond known as Pond 10 in the Fletcher's Creek Subwatershed in Brampton, Ontario.

Since 2005, CVC has recorded water temperature at half hour intervals with continuous data loggers at the ponds inlets and outlets. In addition, grab water quality samples were collected at the inlets and outlets during rain events. During a review of the monitoring program it was determined that in order to be more meaningful the water quality samples should be taken with automatic water samples and flow weighted with water levels from continuous level loggers. Flow weighted water quality samples were collected starting in 2011.

SWM Practices Implemented

- Typical SWM Pond

Figure 7 SWM Pond 10, Brampton

What is being monitored?

- CVC is evaluating the effectiveness of SWM ponds in improving stormwater quality reaching receiving streams.
- In addition, CVC is looking at temperature impacts that may be caused by SWM ponds.

What is being monitored?

- CVC is currently monitoring water temperature at half hour increments from June 1 to September 30 at the inlets and outlets.
- From 2005 until 2010 grab samples were taken at the inlets and outlets during rainfall events.
- Starting in 2011 continuous flow loggers where installed in the inlets and outlets and flow weighted water samples were collected with automatic water samplers.

When did monitoring begin?

- Temperature monitoring and grab water quality samples at the inlets and outlet started in 2005.
- Continuous level logging and flow weighted water quality sampling started in 2011.

Who are the Partners?

- Credit Valley Conservation and The City of Brampton

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APPENDIX B-8 ORANGEVILLE WINTER ROAD SALT STUDY

The Orangeville Winter Road Salt Study was established to monitor chloride levels in stormwater draining to Mill Creek during the winter months. The objective of the study is to characterize the influence that winter maintenance practices (road salt application, snow storage, parking lot salt application) have on chloride and sodium loading to Mill Creek and the Credit River.

Figure 8 Winter Road Salt Study Monitoring Station on Mill Creek

Why is this project being monitored?

- Determine the chloride inputs to Mill Creek from winter road and parking lot maintenance activities from various land uses (Residential, Commercial, Industrial).
- Determine the effect that the Town of Orangeville's snow dump is having on the chloride levels of Mill Creek.

What is being monitored?

- Continuous water level using level loggers at five monitoring stations
- Continuous water quality (dissolved oxygen, conductivity, pH, water temperature, and chloride) using Hydrolab multi-probe water quality meters at five monitoring stations.

When did monitoring begin?

- April 2011

Who are the Partners?

- Credit Valley Conservation and the Town of Orangeville

APPENDIX C:

Detailed Example of Monitoring Plan Design:

Meadows in the Glen - Residential Development

APPENDIX C MEADOWS IN THE GLEN MONITORING PLAN

Purpose

The purpose of the study is to evaluate the effectiveness of various Low Impact Development (LID) methods used in a residential subdivision, with respect to: catchment hydrology, water quality, stream geomorphology, and ecology.

Objectives and Targets

Water Quantity

- Monitoring data will be used to calibrate the models used for designing the LID applications. The models will then be rerun to determine how realistic they were in estimating the required attenuation for the various design storms.
    - Post 2 yr = 0.04m3/s, Post 5 yr = 0.12m3/s, Post 10yr =0.27m3/s, Post 25yr = 0.5m3/s, Post 50yr =0.76m3/s and Post 100 yr=1.06m3/s.

- Determine if there is increased erosion and other stream channel changes in Tributary F resulting from increased flows from the development post construction.
    - Verify through continuous flow monitoring that SWM Pond A is discharging below the critical threshold of 0.10m3/s for Reach 3 of Tributary F during the 24 to 48hr drawdown period.

- Determine if there are any groundwater elevation changes resulting from increased infiltration from the LID measures during and post construction.
    - At source infiltration practices have been designed to infiltrate the first 25mm of rainfall from all roof areas including garages – **estimated annual recharge of 11,000 m^3**
    - Infiltration from grass swales and the bioretention facility is to provide an annual recharge of approximately 10% of the runoff not captured by lot level infiltration – **estimated annual recharge of 6,000 m^3.**
    - Through the installation of a rainfall gauge, flow loggers at the outfalls for both SWM ponds, and continuous groundwater level monitoring equipment within the existing wells, estimate whether the development is meeting the estimated total post development infiltration of **41,000 m^3.**
- Through the installation of continuous flow loggers at both inlets to SWM Pond A, determine how close post development hydrology matches pre-development hydrology.

Water Quality

- SWM Pond A has been designed to provide Level 1 treatment per MOE guidelines.
    - Monitoring to confirm that 80% of TSS is removed from the stormwater produced in the development area on an average annual basis. This will be measured at the inlets and outfall of the SWM pond A.

- Determine if the increased infiltration from the LID measures is having an impact on groundwater quality during and post construction.
    - Monitoring to detect changes in groundwater chemistry.

- Evaluate the need for a permanent pool in LID developments.
    - Through continuous monitoring develop a water budget for SWM Pond A.

- Detect if there are changes in various water quality parameter concentrations in ground and surface water as a result of the development

LID Initiatives

Site Level:

- Swale drainage
- Biofilters

Individual Lots:

- Soakaway pits
- Rain gardens
- Permeable Pavement Driveways

Study Area

The subject site for the study is located in Glen Williams, Halton Region, Ontario. The property was formally used to grow garden plants for Sheridan Nurseries.

The subdivision will be served by two SWM ponds; pond A is located in the northeast corner of the site, while pond B is located in the southwest corner. SWM Pond A will drain to Tributary F, a small tributary that runs between the Meadow in the Glen Site and the Eagle Ridge Golf Club, and discharges into the Credit River. SWM Pond B will discharge down a steep slope and into a wetland and then the Credit River. Figure 2 shows the location of tributary F, SWM Pond A, SWM Pond B, and the approximate drainage area of the two ponds. Tributary F drains and area of approximately 13.6 hectares. SWM Pond A and B drain an area of 23.1 and 12.3 Hectares respectively.

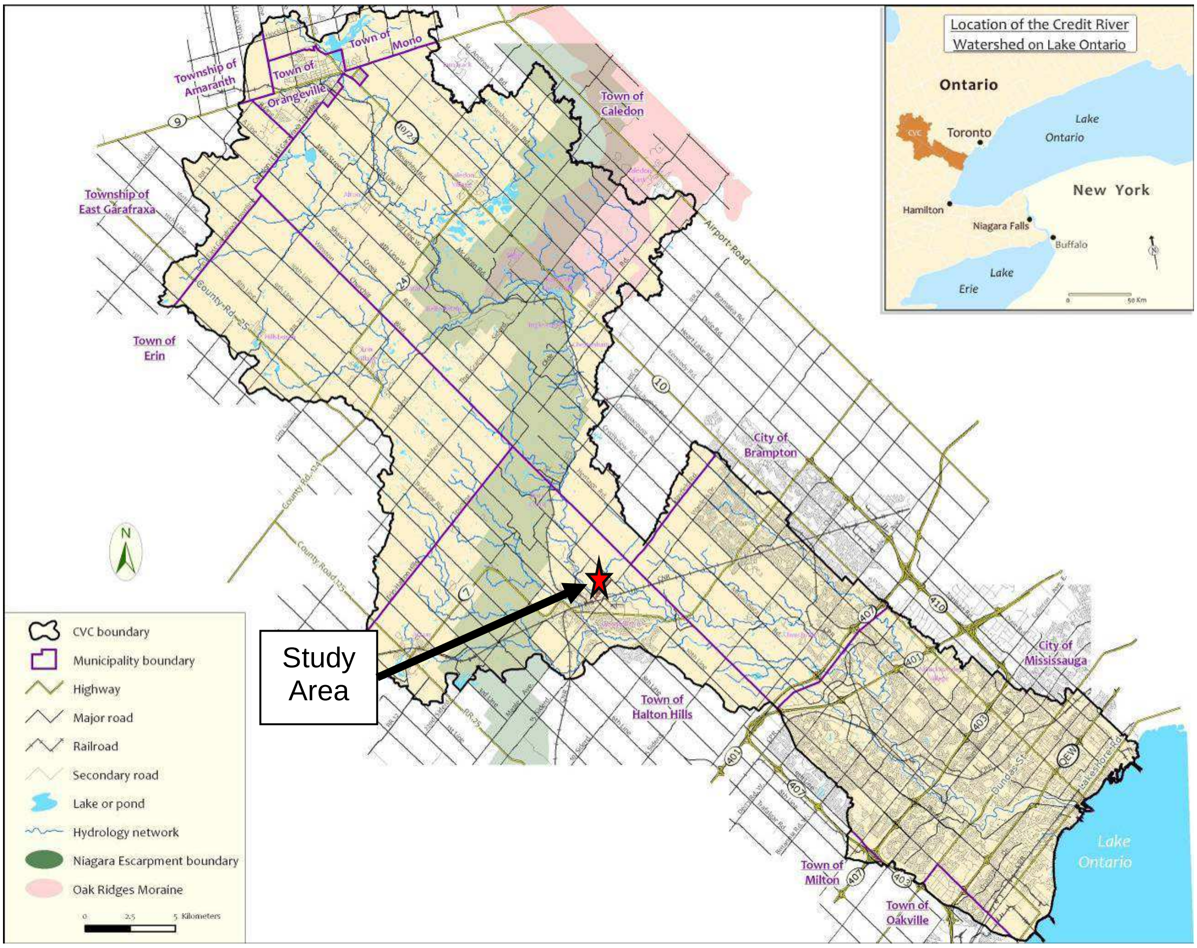

Figure 1: Meadows in the Glen Development within the Credit River Watershed.

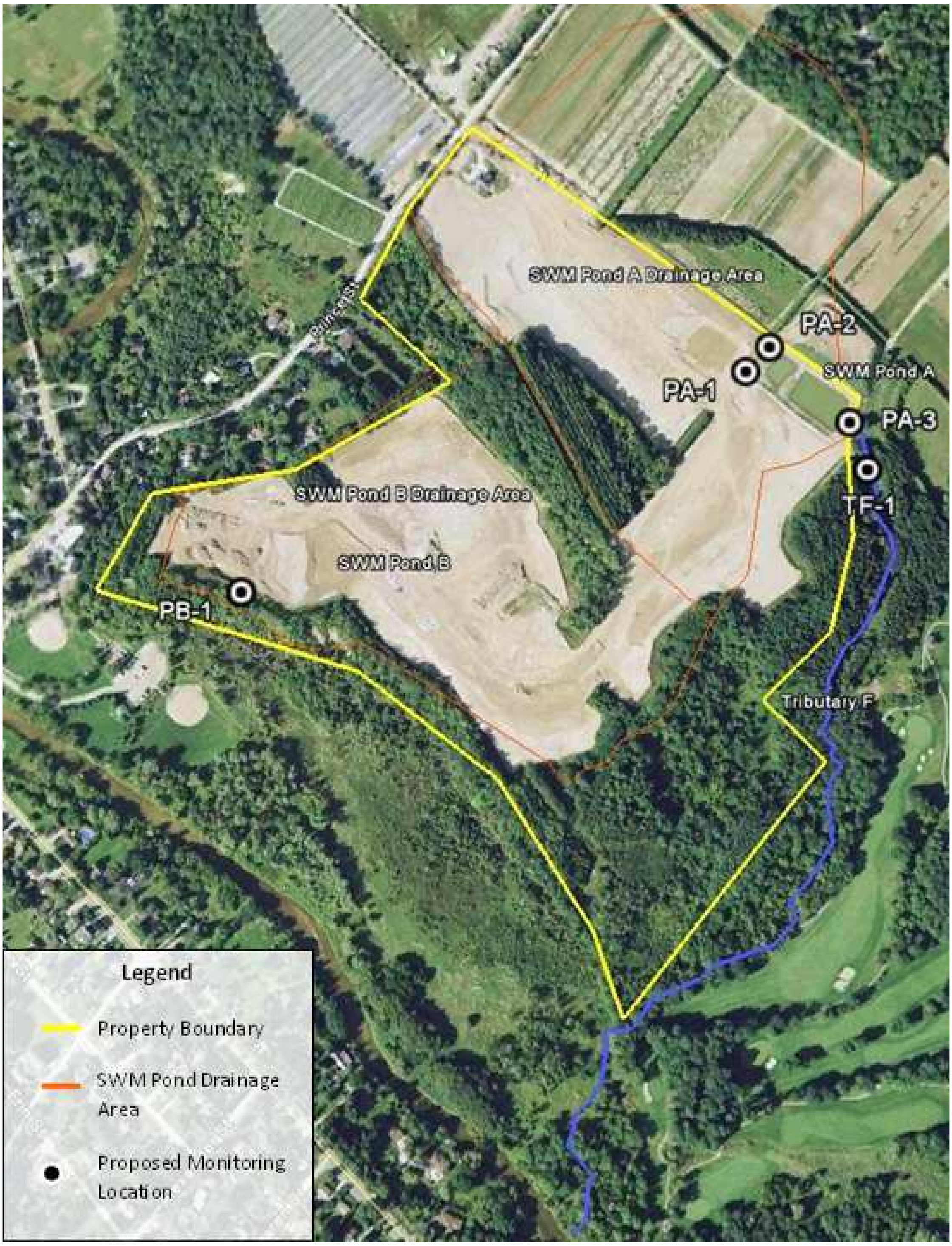

Figure 2: Meadows in the Glen SWM pond locations, drainage areas and proposed monitoring locations

Testing Sites

Five monitoring stations are proposed: both inlets of SWM Pond A, the outlet of SWM Pond A and SWM Pond B, and Tributary F downstream of SWM Pond A. The individual monitoring locations could be utilized as follows:

- SWM Pond A Inflow 1 (PA-1) can be monitored to see the effectiveness of the LID practices put in place at the Meadows in the Glen Development. Data from this station will be combined with data from station PA-2 to get total inflow into SWM Pond A.

- SWM Pond A Inflow 2 (PA-2) can be used to collect background data, as the drainage area is mostly from Sheridan Nursery Lands similar to what was located on the Meadows in the Glen development property. Data from this station will be combined with data from station PA-1 to get total inflow into SWM Pond A.

- SWM Pond A Outfall (PA-3) will be used to determine water quality and quantity leaving the pond and evaluate the need for a permanent pool in LID developments. It will also aid in the calculation of a water balance for the site.

- SWM Pond B Outfall (PB-1) will be used to determine water quantity leaving the pond to aid in the calculation of a water balance for the site.

- Tributary F (TF-1) will be monitored downstream of SWM Pond A to see if the LID measures implemented in the development were successful in mitigating impacts to the tributary.

Work Plan

1) SWM Pond A and B – 10 year plan starting once development is complete

Instrumentation

A site visit was conducted to review the existing drainage infrastructure and assess suitable types of equipment for the monitoring program. A rain gauge will be located at the SWM Pond A outfall sampling site as it is the most suitable location. In addition, an area velocity flow meter will be installed in the outfall of Pond A in the 450 mm PVC pipe (8.5 m long and 4.4% slope), located between the riser and the ditch inlet manhole (assuming limited flows in the ditch). An alternative would be to install a flow control structure (small weir) in the 750 mm (8.2 m long and 2.4% slope) concrete pipe (as opposed to the pipe outlet) and install the flow monitoring equipment there. An area velocity meter will also be installed in the SWM Pond B outfall. It appears that it will be possible to monitor the pond B outfall in one of the pipe sections just as it leaves the pond (e.g., access through manhole 3), close to the riser pipe outfall. The manholes appear to be located at points where the direction changes and pipe size (27”) is reasonable.

The proposed equipment to be located at each of the three SWM Pond A monitoring stations (2 inlets and outlet) includes:
- Rain Gauge (outlet only)
- Flow flume or weir

- Automatic water sampler
- Continuous level logger
- Cellular modem
- Solar panel and battery
- Box for secure onsite equipment storage
- Water temperature logger

The pond B outfall station will have a continuous level logger and box for secure onsite equipment storage and weir only. All equipment will be set to log every 10 minutes, and connected and controlled thought the auto sampler as is shown in Figure 2. Having the majority of equipment from the same manufacturer all connected together will provide savings in staff time on data management and analysis. Data will be stored in the auto sampler's memory and downloaded to a computer either remotely or in person biweekly as minimum.

The site will be visited at a minimum of every two weeks to check battery power, inspect equipment, and make sure everything is operational. To reduce the number of site visits cellular modems will be installed and connected to the Auto Samplers so that equipment can be downloaded and its operation checked from the office more frequently. The modems will also enable activation and control of the Auto Samplers remotely.

<u>Hydrology</u>
A flume or weir will be installed at the three SWM Pond A monitoring locations for accurate level and flow measurements and a continuous level logger will be installed set to record water level at 10-minute intervals. A rain gauge will be installed at the pond outlet and will be set to record rainfall at 10-minute intervals. In addition, a level logger will be installed in SWM Pond A to measure pond water level. Finally, a continuous level logger and weir will be installed in the outlet of SWM Pond B.

<u>Water Quality</u>
Five (5) dry weather grab samples will be collected per year form the Pond A outlet or from Tributary F if there is no baseflow from the pond outlet. Samples will be submitted for analysis of the parameters listed below. Five (5) precipitation events will be sampled per year at all three Pond A monitoring locations with the Isco Auto samplers. Each sampler holds twenty-four (24) one (1) litre bottles.

Samples will be analysed for:

- Chloride
- Conductivity
- pH
- Total Suspended Solids (TSS)
- Nutrients:
    - Total Phosphorus
    - TKN
    - Total Ammonia
    - Nitrate and Nitrite
- Metals
- TOC and DOC
- BOD
- Alkalinity
- *E. Coli* Bacteria

Field water quality measurement will also be taken at the time of sampling if flow is present with a multi-parameter water quality meter. Parameters measured will be:

- Temperature
- pH
- Conductivity
- Dissolved Oxygen

Event sampling will be conducted as follows:

- 2 samples will be submitted per monitoring station per event.
- 1 initial grab sample will be collected in the sampler's first 6 bottles and submitted for analysis.
- The remaining 18 bottles will then be filled to 500 mL every 10 minutes. (Therefore, 1 bottle will be filled every 20 minutes and the program will last for 6 hours. The 18 bottles will then be mixed into 1 flow weighted composite sample and submitted for analysis.
- Samples will be brought to an accredited Canadian Laboratory for laboratory analysis.

In addition, hobo continuous temperature loggers will be installed at each of the stations and set to record water temperature at 10 minute intervals.

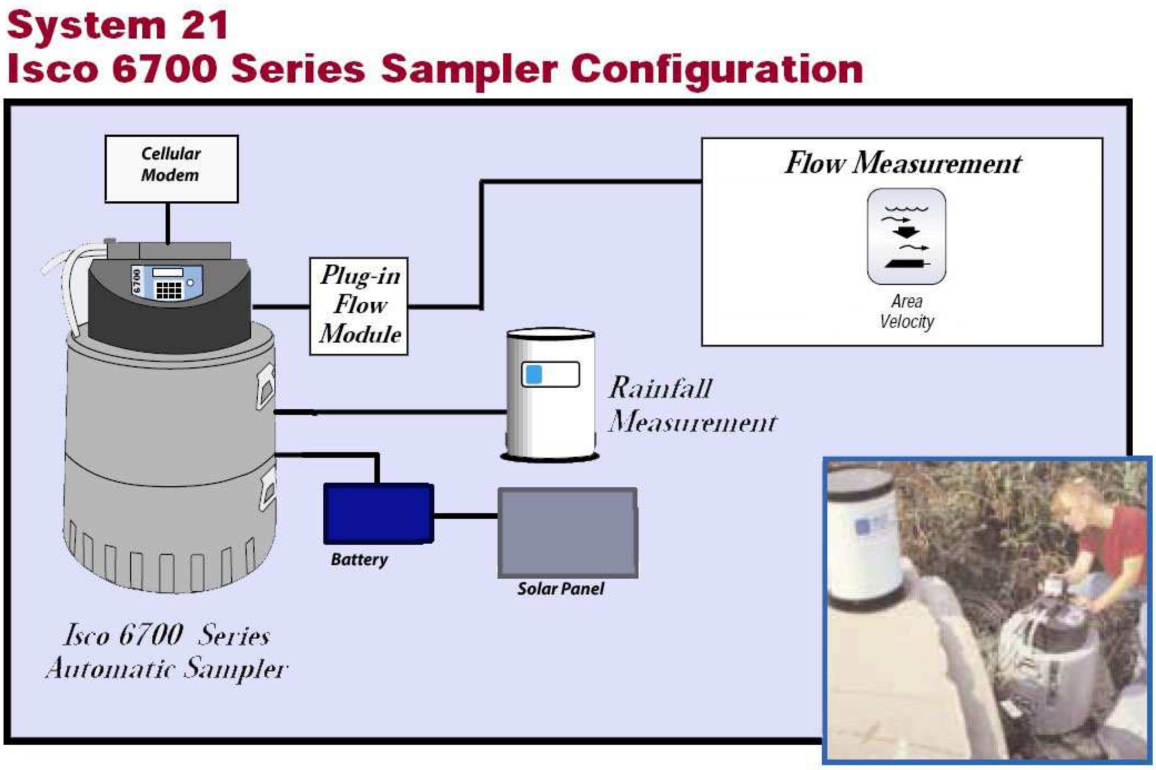

Figure 3: Diagram of how equipment will be connected

2) Tributary F – 10 year plan starting once development is complete

<u>Instrumentation</u>
Due to the low baseflow conditions of Tributary F it will not be possible to calculate a rating curve for the site, by taking manual flow measurements at various depths, as is done in other CVC monitoring programs. Therefore, a flume or weir will need to be installed at the sampling location to ensure accurate level and flow measurements. The proposed equipment for the site is:

- Flow flume or weir
- Continuous level logger
- Box for secure onsite equipment storage
- Continuous temperature logger

All equipment will be set to log every 10 minutes. The site will be visited at a minimum of every two weeks to check battery power, inspect equipment, and make sure everything is operational.

Hydrology

A flume or weir will be installed for accurate level and flow measurements. A continuous level logger will be installed in the tributary and will be set to record water level and flow at 10-minute intervals.

Water Quality

A continuous temperature logger will be installed in Tributary F downstream of the stormwater pond. It will be set to record water temperature at 10-minute intervals.

Fluvial Geomorphology

Annual Fluvial Geomorphology assessments will be conducted along Tributary F downstream of Stormwater Pond A to assess if there is increased erosion and other stream channel changes resulting from increased flows from the development.

Groundwater Monitoring Plan

- **Groundwater Level Monitoring:** Continuous depth loggers will be installed in all existing groundwater wells and the one proposed well. Loggers will be set to record level at 10-minute intervals to match the time step of the other monitoring equipment. This will make plotting and comparing the data between the various pieces of equipment much easier. Wells will be visited monthly to download the loggers and ensure their proper operation. A manual depth measurement will also be taken monthly using a water level tape to ensure the accuracy of the logger data.

- **Groundwater Temperature Monitoring:** Temperature data will be used to monitor environmental change. Monitoring frequency for groundwater temperature should be the same as for groundwater levels. Data will be used to create groundwater thermographs and carry out tentative morphological analysis.

- **Groundwater Quality Sampling:** Groundwater quality will be sampled twice a year (in the spring and the fall) in the existing wells. Samples should be brought to an accredited Canadian Laboratory for laboratory analysis. Parameters should be determined based on hydrogeochemistry condition, land use, and potential contaminant sources.

- **Data Analysis and Reporting:** A detailed morphological analysis will be carried out on the groundwater hydrograph to obtain information on recharge, discharge, storage, and their trends. A detailed water quality data analysis will be carried out to obtain information on hydrogeochemistry and contamination levels. The aim is to establish a causative relation between LID and monitoring data.

Adaptive Program

The program is intended to be adaptive in nature, implying that the program will be continually reviewed and changes may be made to the sampling protocols, methods, and locations as information is gained and conditions change.

References

J. Marsalek and Q. Rochfort. 2008. Observations on Monitoring the LID Project “Meadows in the Glen”. Memo to Credit Valley Conservation and Intercorp.

Project Partners