LOW IMPACT DEVELOPMENT CERTIFICATION PROTOCOLS:

BIORETENTION PRACTICES

Version 1.0
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Acknowledgements

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Refer to CVC's LID Guidance Docuements for more information:

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Preface

Who Should Read This Guide?

This guide helps municipalities and property owners implement innovative LID practices. Information in this guide is aimed at the following audience:

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

This guide is also for anyone involved in funding or making decisions about municipal infrastructure and stormwater management including councillors, commissioners and the public.

Why should I read this guide?

The *LID Certification Protocols: Bioretention Practices* guide provides the reader with a thorough understanding of certification protocols for LID bioretention practices. This can reduce the risk to the owner when issuing a certificate of completion or accepting LID practice(s). It ensures a properly functioning facility that will not require costly near or long term repairs.

How will this guide help me?

This guide presents LID certification protols and practical tools to make the process of accepting LID more formalized within your muncipality or development. This reduces the risk and liability associated with adopting innovative stormwater management practicies. This guide helps you:

- Understand contract and administrative strategies for cerfitifcation
- Understand the different levels of certification, their advantages and disadvantages
- Understand the tests required for different levels of certification
- Understand the corrective actions required to restore a bioretention LID practice
- Ensure long-term success with the tools to properly certify the LID, avoiding costly repairs in the future

Where should I go for more information?

Visit Credit Valley Conservation's *Be a Leader* website (**bealeader.ca**) For more information on the design, construction and lifecycle activities of LID practices.

Several symbols are used in this guide. Here is a reference key to help you find what you are looking for:

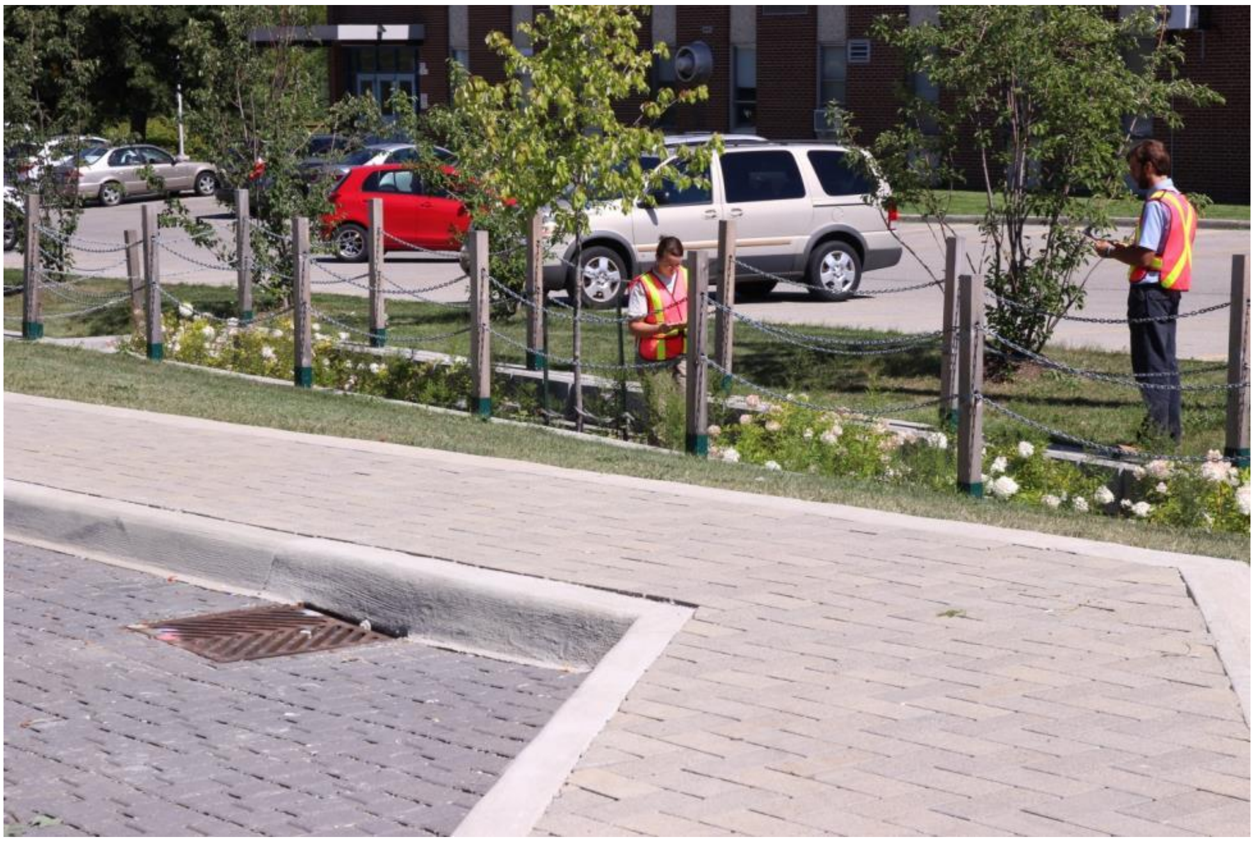
 Example, case study or further reading to provide better understanding or context

 *Tip, idea or lesson sharing experiences*

 *Health and safety reminders for a safe workplace*

 Financial implications or expenses to consider

Overview



I. Business Case

Municipalities and businesses (property owners and managers) have protocols in place to thoroughly inspect work done on their property. They ensure that work is done in accordance with the original design, that performance is acceptable and that the design is functional. As low impact development practices become more commonly used, municipalities and property owners need methods to certify that these practices have been designed and constructed properly. Certification protocols also ensure that knowledgeable personnel (e.g. third party inspector, design engineer or permitting agency) evaluate whether LID practices have been installed properly before the contractor is released of responsibility. A thorough certification protocol reduces the risk to the owner and will save money in the short and long term.

For all construction projects as well as LID projects, the pace and extent of construction may preclude inspections and certifications from ensuring the critical design elements of each LID practice. Certification of the LID practice should take place when all construction is complete and drainage areas are stabilized. The certification protocol is the last opportunity to identify issues related to improper design, improper construction, and/or unforeseen site condition issues. LID certification protocols ensure that the property manager receives a practice that is functioning properly and will not require costly near or long term repairs. Certification protocols are not only for LID projects, but are part of many construction projects. They are similar to many regular construction inspections or warranty periods.

Although LID is a growing market in Canada, it shares commonalities with stormwater management ponds and other end-of-pipe features common to new development. Some commonalities between LID and end-of-pipe practices include:

- Meet requirements of the planning and plan review process
- Require appropriate sizing to function properly
- Use proper erosion and sediment control (ESC), although LID is more robust
- Require certification protocols to verify the practices are constructed as designed
- Provide water quality treatment and storage
- Require regular maintenance to ensure long term performance
- Require monitoring to ensure water quality targets are met

Over the past five years, CVC's municipal and development industry partners have called for improved reporting, tracking and certification of LID BMPs. As governments set watershed goals for pollution reduction and expand stormwater rate credit programs, there is a growing need for verifiable confidence in the outcome of an implemented LID practice. An established certification methodology and requirement will provide the property owner, municipality, conservation authority and Ministry of Environment and Climate Change with a high level of confidence that the practice was designed and constructed properly, will function over the long term and provide the intended benefits.

Under the Ontario Water Resources Act, stormwater approvals often require the owner of the stormwater system to conduct ongoing maintenance and monitoring. [1] This includes documenting inspections and maintenance. Having certification protocols and regular inspections provides evidence of duty of care and due diligence, reducing risk and liability and strengthens positions in

[1] Zizzo, L., Allan, T., Kocherga, A. 2014. Stormwater Management in Ontario: Legal Issues in a Changing Climate

event of a claim. Municipalities are being sewed for not maintaining stormwater infrastructure and not implementing stormwater management plans. As a land owner, the higher level of certification conducted the lower the risk of negligence you assume.

Inspection and monitoring also play into asset management. Provincial and federal funding for infrastructure requires municipalities to do asset management plans. Through good asset management, cost savings can be achieved by spotting deterioration through inspections early on and taking action to rehabilitate or renew the asset through maintenance. [2] It results in informed and strategically sound decisions that optimize investments, better manage riskand take into account the potential impact of other factors, such as climate change. Monitoring is a key component of asset management, adaptive management, documenting management decisions to reduce liability and risk and demonstrating success and transparancy to stakeholders.

In the water sector, municipal operation departments that oversee residential drinking water systems must document their infrastructure maintenance, rehabilitation, and renewal programs and monitor the effectiveness of their maintenance programs as part of the quality management system required as a condition of accreditation[2]. The Water Opportunities Act, 2010 builds on this by setting the framework for a performance measurement regime and sustainability planning for water, wastewater, and stormwater over the lifetime of the infrastructure assets.

Municipalities are also implementing stormwater user rates. For example, the City of Mississauga stormwater user rate is set to come into effect January 2016. Businesses and institutions can apply to a credit program if they have their own stormwater measures or practices on their property that benefit the City's stormwater program. In order to ensure that these LID practices are functioning as designed, municipalities may require the land owner to monitor practices and document inspections and maintenance.

[2] Ministry of Infrastructure. 2012. Building Together: Guide for Municipal Asset Management Plans.

Stormwater ponds provide valuable lessons for LID. A 2007 survey of southern Ontario municipalities found that certification and monitoring protocols for stormwater ponds to be weak or non-existent.[3] This has resulted in many ponds that have been assumed by the municipality that do not meet design requirements. A study of 98 ponds in the Lake Simcoe Conservation Area found that nearly half failed to meet their design level of service.[4] To meet the design level of service these ponds would have to be dredged earlier than anticipated, which is costly and may not be budgeted for. Both studies recommend more rigorous certification protocols before project acceptance, including at a minimum an as-constructed survey.

In the United States, LID practices have run into similar issues. The Center for Watershed Protection 2010 survey of stormwater best management practices (BMPs) in the James River watershed found approximately half (47 per cent) of the 72 BMPs deviated in one or more ways from the original design. The wide range of opportunities for LID failure includes[5]:

- Clogged or compacted infiltration areas
- Poor pre-treatment and/or erosion from upland drainage areas;
- Poor vegetation establishment
- Improper substitutes for materials and methods
- Incorrect inlet and outlet structure elevations or locations
- Lack of training and education related to post-construction operation and maintenance

[3] Drake J., Y. Guo. 2008. Maintenance of Wet Stormwater Ponds in Ontario. Canadian Water Resources Journal, 33(4): 351-368.

[4] Lake Simcoe Region Conservation Authority (LSRCA). 2011. Stormwater Pond Maintenance and Anoxic Conditions Investigation. Final Report

[5] Hirschman, David; Drescher, Sadie and Woodworth, Laurel. 2009. Stormwater BMPs in Virginia's James River Basin: An Assessment of Field Conditions & Programs. Center for Watershed Protection Technical Report.

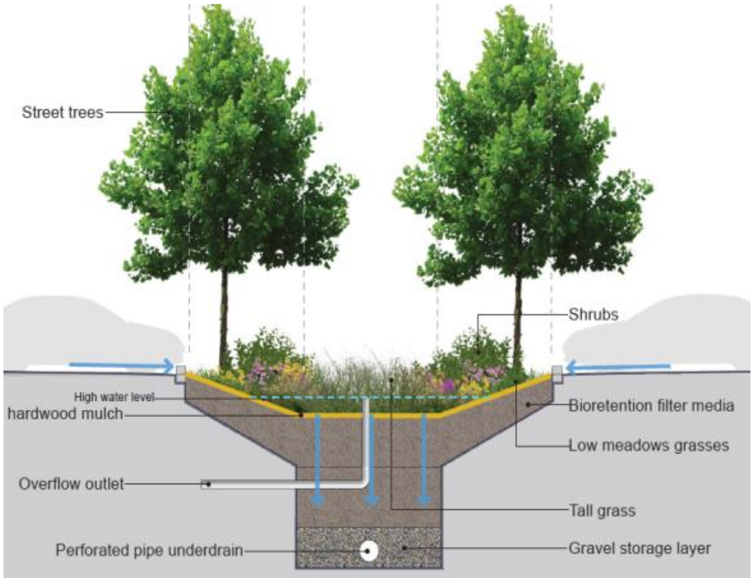
	Why conduct LID Certification Protocols?
Developer	- Gain a clear understanding (between all parties) of design and construction expectations before entering into an agreement - Set out a standardized certification process at the beginning of the project so all parties can anticipate monitoring costs and potential project delays - Gain insight into future LID construction projects - Meet permit requirements (ECA, subdivision agreement) - Gather data needed for stormwater credits - Receive Certificate of Completion sooner - Reduce subjectivity in what constitutes a pass/fail
Designer	- Gain a clear understanding (between all parties) of design and construction expectations before entering into an agreement - Set out a standardized certification process at the beginning of the project so all parties can anticipate monitoring costs and potential project delays - Gain insight into future LID construction projects - Use information gathered to enforce repairs - Reduce subjectivity in what constitutes a pass/fail
Landowner (municipality)	- Gain a clear understanding (between all parties) of design and construction expectations before entering into an agreement - Set out a standardized certification process at the beginning of the project so all parties can anticipate monitoring costs and potential project delays - Gain insight into future LID construction projects - Minimize risk and liability - Save money on expensive repairs caught before the warranty period ends - Use information gathered to enforce repairs - Ensure design targets are met - Address design and construction issues sooner - Gather data to show when the LID practice is failing - Gather data to show when maintenance is needed - Gather data to support asset management and life cycle costing - Reduce subjectivity in what constitutes a pass/fail

II. Background

This document provides details on four levels of certification protocols (simple to complex) that can be used to certify that bioretention practices were constructed as per the design and will function properly. A flow chart is provided in Section III, which can be used to determine which level of certification should be used. Detailed directions on how each protocol is performed are provided in the following chapters. These certification protocols can be adopted as is or adapted by a municipality or property owner.

Bioretention practices make use of vegetated practices that temporarily store, treat and infiltrate stormwater runoff. The most important component is the bioretention soil media. The bioretention soil media is made up of a specific ratio of sand, fine soils and organic material. Bioretention can be integrated into a diverse range of landscapes, including existing parking lot islands, gardens and lawn areas, They are best located within (or adjacent to) hard surfaces like roadways, parking lots, buildings and pedestrian pathways. These surfaces generate large amounts of runoff that can be treated by bioretention practices. Depending on native soil infiltration rate and physical constraints, the practice may be designed without an underdrain for full infiltration, with an underdrain for partial infiltration or with an impermeable liner and underdrain for filtration only.

Example bioretention practices (Elm Drive, Lakeview, IMAX)



Typical cross-section of a partial infiltration bioretention practice

Generally, throughout the life cycle of a stormwater management system, there are five stages in which a review or inspection need to take place. This ranges from the initial review of the design through to long term inspection and verification by the management authority. This document focuses on approaches and methodology for the third stage, post-construction certification.

	Stage 1 **Design and Plan Review**	**Stage 2** **Construction Inspection**	**Stage 3** **Post-Construction BMP Certification**	**Stage 4** **Routine Maintenance Inspection**	**Stage 5** **Municipal Performance Verification**
Purpose	Ensures the BMP is properly designed and reviewed	Ensures BMP is installed correctly through all stages of construction	Ensures BMP is constructed correctly and functioning	Ensures the BMP is properly maintained and functioning	Ensure BMP exists and is providing the pollutant removal it was designed to achieve.
Audience	Design engineer/ plan review	Trained inspector, contractor, site engineer	Trained engineer or inspector	Property owner/ maintenance staff	Trained municipal staff
Timing	during the design process	throughout construction	happens at project acceptance	monthly to semi-annual	typ. 3-5 years

BMP life cycle stages of review and inspection

Once a contractor completes a job, LID practices may or may not be installed per the site plans. Following a post-construction period of Best Management Practice (BMP) stabilization and vegetation establishment, a site developer completes a Certificate of Completion that verifies BMP specifications and performance for approval prior to property transfer.

III. Criteria for LID BMP Certification

The certification protocols for bioretention were developed to meet these goals but with the following principles or criteria. These criteria should also guide the development of individual municipal LID BMP certification programs. When verification is not completed by a regulatory agency there needs to be clear expectation in terms of level of authority and reporting methods including communication and timing for the person(s) who will assume these responsibilities. Verification requires a range of skills, experience and knowledge. An accountable professional must be the lead to ensure all aspects of the verification process have been completed properly and in a timely manner.

1. Constructed to Design Specifications. Municipalities and property owners/managers (industrial/commercial/institutional) will need to verify that stormwater BMPs are installed properly and meet or exceed the design standards and hydrologic function prior to project acceptance. This verification may take place immediately after construction or following a warranty period of 1-2 years. This initial verification is provided either by the BMP designer or the local inspector as a condition of project acceptance. The verification would call upon all construction and installation records that should have been outlined in the tender documents for ensuring proper construction to design specifications. The target audience includes provincial ministries (MOECC) to ensure that BMPs meet Level 1 Enhanced protection. It also includes stormwater management system designers and consultants who need to ensure their designs meet expectations.

2. Identify Monitoring Infrastructure Needs Prior to Construction of BMP . As part of the initial stages of the design process, the required monitoring infrastructure should be identified and accounted for prior to construction. For instance, if the LID BMP is designed to provide volume reduction and flood management, then flow monitoring equipment needs to be incorporated in the design to ensure adequate space availability. If LID BMPs are designed for water quality improvements and removal of certain pollutants, then automated samplers need to be incorporated into the design and installed within manhole structures for composite and grab sampling. If the main intent of the LID practice is infiltration and storage, then observational wells/piezometers need to be incorporated in design plans.

3. Public Safety. While it may be impractical or impossible to eliminate all safety risks associated with stormwater management practices, most risk can be mitigated through proper design, construction, maintenance and public awareness. Generally, LID BMPs are inherently safer than large centralized stormwater management practices like wet ponds. Typical public safety inspection tasks for LID include checking ponding depths and drawdown times, eliminating trip hazards and ensuring that vegetation doesn’t obscure important sightlines.

4. Pre-treatment Practices. Filtration/infiltration BMPs require pre-treatment to prevent plugging of filtration beds from small soil fractions, particularly clays, thereby reducing water infiltration rates. Typical pre-treatment measures include the use of perennial grass buffers and vegetated swales, urban forests with canopies that enhance rainfall interception, hydrodynamic separators or swirl devices, sedimentation forebay and the use of catch basins with enhanced sedimentation. Upland contributing areas should be examined for the presence and extent of upland pre-treatment measures and compared to the BMP design specifications. Seasonal effects on pre-treatment practices should also be noted (e.g. loss of tree canopies could mean excess leaves plugging filtration/infiltration beds, upland turf conditions due to annual species die-off etc.). Upland drainage area issues should be noted for maintenance or alteration of practices.

5. Certification method will differ depending on the class of stormwater BMP. There are broad categories of BMPs in which the certification methodologies will be similar for each as all BMPs work through infiltration (e.g. bioretention, infiltration galleries, permeable pavements, dry swales etc.). This guide only focuses on certification of bioretention practices.

6. Building upon existing municipality capabilities. Inspection and certification of LID BMPs is a new task for municipalities. To limit administrative burden, municipalities may choose from a range of certification methods varying from simple to complex, to best fit their management goals as well as their staff's training and experience..

IV. Contract and Administrative Strategies for Certification

Potential contract and administrative mechanisms for ensuring that SWM practices are constructed correctly and ready to be assumed by the property owner include:

Performance Bonds, Letters of Credit and Cash Surety

The most common method for certifying project completion entails a performance bond submitted by the contractor to the owner as a condition of the contract. Contract language for certification of project completion should specifically require certification of LID practices. In this case, the designer would be best equipped to handle the final certification process on behalf of the owner. This system may fail in the case where the implementation of the LID practices is not in the owner's self-interest.

Subdivision Agreements and Permitting Requirement

The regulatory authority (e.g., the municipality or the conservation authority) must require a performance surety as part of their permitting process, which specifically requires certification of LID practices and performance. In this case, qualified regulatory personnel would handle the final certification process if the local regulatory authority (e.g., the municipality or conservation authority) requires a performance surety as part of their permitting process, which specifically requires certification of LID practices. Final certification should be performed by qualified regulatory agency personnel.

Statutory Holdback (Identified in Tender Documents)

The owner can specify in the tender documents to retain a certain percentage of statutory holdback of the total value of the work done for a period of 12 months from the date of final completion.

Performance Surety Requirement Example

Capitol Region Watershed District (Ramsy County, MN)

A cash surety in an amount set forth below must be submitted to the District with each permit application for the activities described below:
Description of Activity Cash Surety Amount
1. Grading associated with Development $2,000/acre
2. Stormwater Management Facilities 1.25% of estimated construction cost
The surety amount will be calculated as follow:
(Acres of Development * $2,000) + (1.25 * Est. Construction Cost of Stormwater Facilities) = Surety

An applicant may submit a performance bond or an irrevocable letter of credit to the District to secure performance of permit conditions for activities for which the required surety amount as determined above is in excess of $5,000. The performance bond or letter of credit must be submitted with the permit application. The first $5,000 of the surety must be a cash surety. For amounts over $5,000, a cash surety, performance bond or letter of credit is acceptable.

Checkpoint Inspection

The tender document should lay out a series of "checkpoint" inspections completed by a qualified professional during the various critical phases of construction and installation of LID practices. This will allow for earlier detection of any potential issues prior to construction completion.

Compliance Case Study- Subdivision Development, City of Brampton

The example subdivision is a 5.7 hectare 90 lot single family home residential development and the first fully LID residential neighborhood in Brampton. Its design manages all onsite stormwater runoff through LID practices, which include permeable pavers, grass swales, rain gardens and a bioswale. The LID system is design to retain all rainfall events up to 15mm over the entire site and convey all flows through the LID treatment system.

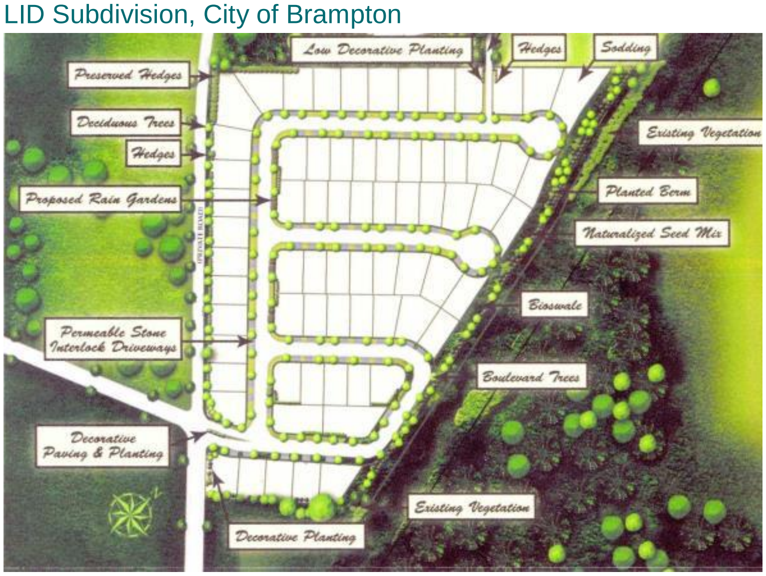
Operation and Maintenance

The Ministry of the Environment's Environmental Compliance Approval (ECA) requires *level one* visual inspection and record keeping. All inefficiencies observed during inspection are remediated at the expense of the owner. All maintenance and inspections must be recorded and stored at the owner's office for inspection by the Ministry.

Monitoring and Reporting

To ensure the developments unique stormwater control system functions according to design, the ECA requires *level two and three* monitoring and reporting plan in accordance with the Ministry's sampling and analysis procedures. A performance assessment report is prepared by the owner or a consultant providing the results of performance assessment to the Ministry. All records and reports must be retained for a minimum of 5 years from the date they were created.

LID Subdivision, City of Brampton



V. How to Use this Guide

Property owners and municipalities have varying capacities for performing certification protocols and monitoring. Some LID practices require varying levels of monitoring scrutiny from very little for the simple residential rain gardens to more intense for engineered bioretention cells treating a hectare of parking lot runoff. This document presents four levels of certification protocols:

- Level 1: Visual Inspection
- Level 2: Capacity Testing
- Level 3: Continuous Water Level Monitoring
- Level 4: High-Intensity Monitoring

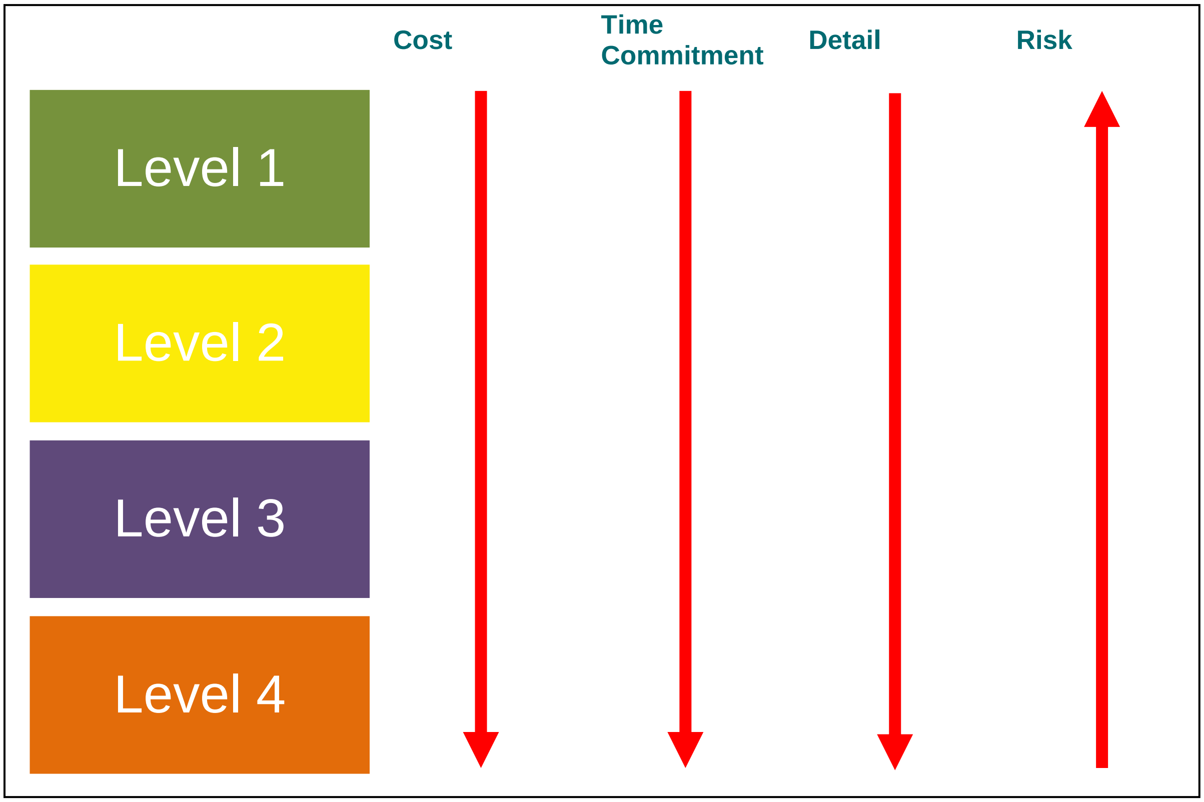
This certification process was adapted from research by the University of Minnesota and the Minnesota Pollution Control Agency These certification protocols can be adopted as is or adapted by a municipality or property owner.

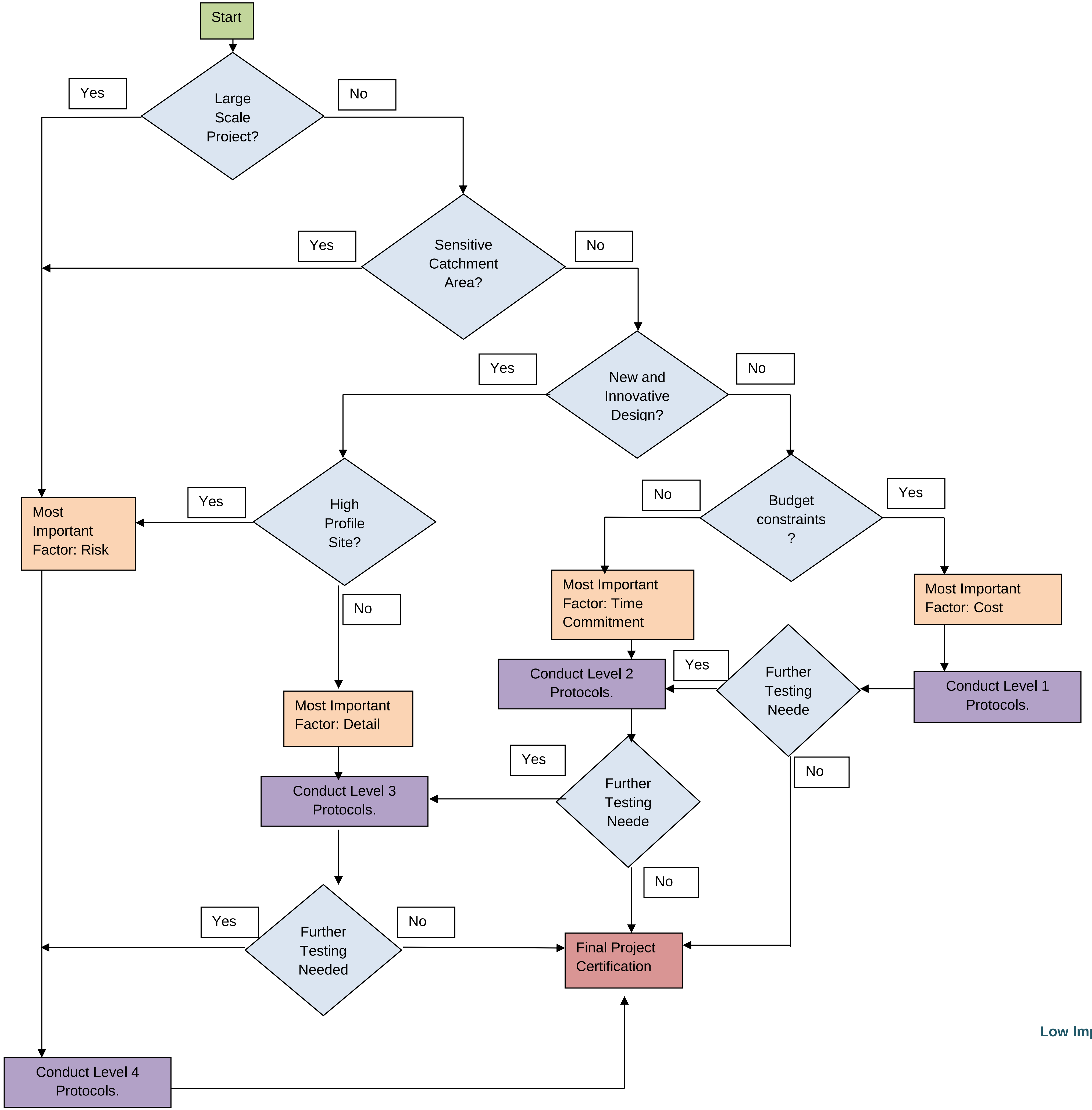
The flow chart below provides guidance for choosing the appropriate level of certification to be used for varying types of projects. Once the level of certification is chosen, Table 1 outlines the certification protocols for each level. Detailed directions on how to conduct each protocol are provided in the following chapters. Each level of certification builds on the previous level. For example, Level 4 Certification Level includes protocol tests from Level 1, 2 and 3, in addition to tests unique to Level 4.

The highest certification level chosen for the project will depend on the project goals and objectives and the scope of the project. However, during the course of the certification protocols you may require further testing, which could increase the level of certification for the project from a Level 1 to a Level 2, 3 or even 4 depending on the nature of the issue. It is important to keep in mind that cost, time commitment and level of detail increase with increasing level of certification, whereas, risk decreases with increasing level of certification. Table 2 at the end of the section outlines the advantages and disadvantages of each level.

This guide includes a brief description of Level 3 and 4 monitoring intended to inform the reader about these methods of monitoring. For more comprehensive guidance for conducting Level 3 and 4, refer to CVC's *LID Monitoring Guidebook* for more information.

For more information on the monitoring program at one of our established LID sites, please refer to the *Elm Drive Technical Monitoring Report.*


Cost
Time Commitment
Detail
Risk
Level 1
Level 2
Level 3
Level 4



Due to the variability of LID projects, each project is unique and the level of certification is highly depending on the characteristics of each project. This flow chart can be used as a tool for selecting the level of certification that best fits the project.

Above all, monitoring must meet the minimum permitting requirement. However due to the nature of the project, some projects may require a higher level of certification than permitting requires.

Please note as you move forward with certifying the LID bioretention feature(s), if challenges are encountered additional testing may be needed to properly identify the cause of the problem and the recommended actions required.

Once the chosen level of certification is completed, further testing will be dictated by the results of each individual protocol. Refer to each certification level for more detailed direction.

Certification Levels and Protocols

	Certification Protocols									
Certification Level	**Checklist Inspection (p.__)**	**Photo and Video Documentation (p.__)**	**Vegetation Survey (p.__)**	**Sediment Inspection (p.__)**	**Soil Tests (p.__)**	**As-Built Survey (p.__)**	**Infiltration Tests (p.__)**	**Synthetic Runoff Test (p.__)**	**Continuous Water Level Monitoring (p.__)**	**Continuous Water Flow and Quality Monitoring (p.__)**
Level 1: Visual Inspection	✓	✓	✓	✓						
Level 2: Capacity Testing	✓	✓	✓	✓	✓	✓	✓	✓		
Level 3: Continuous Water Level Monitoring	✓	✓	✓	✓	✓	✓	✓	✓	✓	
Level 4: High-Intensity Monitoring	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

Each level of certification builds on the previous level. For example, Level 4 Certification Level includes protocol tests from Level 1, 2 and 3, in addition to tests unique to Level 4.

VI. Certification Levels

Level 1 - Visual Inspection

Considering the minimal effort and cost required for visual inspection, visual inspection should be used as the initial assessment tool for all stormwater treatment practices. Visual inspection involves inspecting a stormwater treatment practice for evidence of malfunction or deviation from the design plan. This can be accomplished with brief site visits on a sunny day, rainy day and just after a rainstorm, using the original design plans and a checklist.

Visual inspection can be used to quickly and cost-effectively determine if, and potentially why, a stormwater treatment practice is not operating properly.
Simplified techniques focus on these aspects:

- General confirmation of site draw-down time (hours)
- Inspection of soil properties
- Submission of detailed construction logs, photographic inventories from designer and contractor (from installation).
- Presence of ponded water on site. If a stormwater treatment practice is determined to be non-functional based on visual inspection (e.g. it contains ponded water longer than 24 hours (or 48 hours) after the end of the last precipitation event), no further performance assessment is warranted until the stormwater treatment practice is repaired or replaced.
- Vegetation surveys that focus on plant health, plant cover, unwanted plants, and overall aesthetics
- Visual inspection of the water level can be performed by visiting an LID practice during or shortly after a rain event greater than 15mm in depth.
- Sedimentation monitoring and more in-depth vegetation surveys - these tasks help establish the necessary maintenance schedules for sediment removal from inlets/pre-treatment areas and vegetation care. Importance should be paced on observing preferential flow paths that can be prone to plugging.

Visual inspection alone cannot provide quantitative information about the stormwater treatment practice performance. For quantitative information on performance, complete level 2, 3, and 4.

Level 2 – Capacity Testing

A step beyond visual inspection involves collecting additional data through testing and measurement:

- Soil sampling and testing - ensures that the installed bioretention soil meets the specification. Timeframe for completion will be dictated by soil sample testing by soil laboratory.
- Elevation surveys - confirms that the depths, storage volumes, and drainage areas correspond to the design plan.
- Infiltration testing - performing field infiltrometer or Permeameter tests will provide an estimate of expected drawdown times.
- Synthetic runoff testing - uses a clean water source (e.g., a fire hydrant or water truck), which is applied to the stormwater treatment practice in a controlled manners (to prevent erosion and scouring of the landscaped surfaces) and while performance is measured. Visual observation of water levels will establish the drawdown time under controlled conditions.

These tasks can be performed with commonplace equipment or readily available services and within a short timeframe (1 week). This level of certification will establish if the practice was built to the design plan, including the bioretention soil composition, the storage volume, and drainage area. The infiltration testing will provide an estimation of expected drawdown times depending on the number of infiltrometer or Permeameter measurement tests spatially distributed throughout the practice and performed at different times of the year.

These testing protocols will not provide the same level of accuracy as the real world monitoring that occurs in level 3 and 4.

Level 3 - Continuous Water Level Monitoring

After infiltration testing and synthetic runoff testing (level 2) have been conducted, continuous water level monitoring can be used to measure site infiltration rates. A new and innovative method of tracking runoff infiltration through the soils has been developed based on use of inexpensive continuous water level/temperature data loggers. This type of monitoring provides a cost-effective alternative by tracking temperature and groundwater levels over time including evaluation of seasonal and winter infiltration performance, potentially affected by frozen soils.

One of the larger BMP performance questions facing cold climate stormwater managers is the performance of BMPs during the winter months. Traditionally, infiltration devices have not been given much credit for cold climate performance due to perceived soil freezing. Urban heat island effects from impervious cover is thought to cause more urban freeze-thaw cycles than say forests or meadows (MIDS, 2012). Continuous recording water level/temperature data loggers allow more detailed annual and winter infiltration performance tracking.

Subsurface water levels and temperatures can be continuously monitored with a water level logger installed in an observation port/well. For a continuous water level assessment, the following conditions must be met:

1. A perforated observation well (or piezometer) must be installed which extends from the bottom of the practice to ~300 mm above the surface.
2. A water level logger (small, in-situ relatively inexpensive monitoring equipment) needs to be installed inside the well.
3. A rain gauge must be in the vicinity, onsite is preferable, but within 5 km is acceptable. The rainfall data and known drainage area are necessary information for comparison to the water level drawdown data.

Depending on the type of loggers selected, a barometric pressure logger may also be required to compensate the data to get accurate measurements. If you have multiple sites, one barometric pressure logger can be used as long as they are within a few kilometres of each other. Check with your equipment manufacturer/supplier to determine your requirements.

Water level data in combination with rainfall data can be used to determine how long it took the practice to drain down after the end of a storm event and what size storm events resulted in overflows.

Level 4 – High-Intensity Monitoring

If Level 2 or 3 do not achieve the goals of the assessment or further testing is required, a more intensive monitoring program should be considered. High-Intensity monitoring is the most comprehensive and expensive assessment technique and can be used to effectively document water volume reduction and peak flow reduction for most stormwater treatment practices by measuring discharge during natural runoff events.

This level of monitoring is recommended for regional demonstration purposes when such a stormwater practice is being implemented for the first time in that jurisdiction or development context (e.g. pilot testing of a new technology, challenging soil or geologic contexts, unique or hybrid facility design). Another situation where this level of monitoring might be warranted is if the facility has been designed to meet higher standards due to the sensitivity of the receiving water or presence of species of concern.

Example stormwater monitoring station (Source: CVC).

To assess runoff volume and pollutant load reduction, peak flow reduction, or both by monitoring a stormwater treatment practice, the inflow(s) and outflow(s) must be measured or estimated as in conducting a water budget. The summation of the inflows can then be compared to the summation of the outflows to determine the runoff volume reduction, peak flow reduction, or both. typical urban runoff events are flashy (rapid response) and require continuous flow measurement (or estimation).Pollutant loading changes will require state-of-the-art automated sampling devices to obtain flow-pace or time-weighted sampling that coupled with continuous flows allow estimation of loads.

The advantages and disadvantages of the varying certification levels

Certification Level	Objectives	Time Requirement	Advantages	Disadvantages	Recommended Project Type
Level 1: Visual Inspection	Determine: - constructed to design plan - Malfunctioning and recommendations to fix. - sedimentation rate	During warranty period 3-6 site visits over 1-2 years	- quick - inexpensive	- Limited knowledge gained in terms of quantitative storm water benefits. - May not catch all problems	Small scale retrofit or new LID project such as: - Residential, church or a school property - Small commercial property (Shoppers Drug Mart, etc.)
Level 2: Capacity Testing	Determine: - storage capacity - infiltration rate and drawdown time - sedimentation rate	During warranty period: (1 – 2 years)	- less expensive - no equipment left in field -short timeframe - provides quantitative values for runoff storage and infiltration. - Confirm when maintenance is required	- requires special equipment to perform test. - synthetic runoff test cannot be used without sufficient water supply - LID practice may perform differently with varied antecedent conditions	Small to medium scale retrofit or new LID project such as: - Residential, church or a school property - Small commercial property (Shoppers Drug Mart, etc.)
Level 3: Continuous Water Level Monitoring	Determine: - storage capacity - infiltration rate and drawdown under various conditions - sedimentation rate - volume reduction	During warranty period or post establishment (1-2 years)	- controlled experiments - more accurate - equipment left in the field, but hidden in observation well - Provide municipalities information to get credits from stormwater rates - Reduces risk and liability - Reduced subjectivity in what constitutes a pass/fail	- Higher cost and time commitment than level 1 and 2.	Medium to large scale retrofit or new LID project such as: - residential subdivision/building, - Commercial real-estate plaza. - Public buildings/lands - Public road right of way.
Level 4: High-Intensity Monitoring	Determine: - storage capacity - infiltration rate and drawdown time - sedimentation rate - flow, volume, and water quality performance	During warranty period or post establishment (1 - 3 years)	- Most detailed - Most accurate - Includes drainage area specific evaluation - Provide municipalities information to get credits from stormwater rates - Reduced risk and liability - Problems are addressed at the beginning - Data to support when practice is failing - Data to support when maintenance is needed - Information can be used to support asset management and life cycle costing - Reduced subjectivity in what constitutes a pass/fail	- Requires knowledgeable personnel - High cost to undertake - Equipment is left in field	Medium to large scale retrofit or new LID project such as: - residential subdivision/building, - Commercial real-estate plaza. - Public buildings/lands such as major parks. - Public road right of way.

* Modified from University of Minnesota's *Assessment of Stormwater Best Management Practices*

Level 4 High-Intensity monitoring can be a key factor in identifying site deficiencies not caught by visual inspection. By examining the performance of the LID practices throughout multiple precipitation events, high-intensity monitoring identified an issue with the flow of stormwater through the bioretention units. While flow was being observed through the LID practices on the south side of the street, little to no flow was observed from those on the north side. From the data gathered, it was determined that the inlet design was not efficient at accepting water so the inlets should be replaced with a more efficient design.

Bypassing of bioretention units during a rainfall event

Example of inlet design that is more efficient to replace original inlet design.

Level 1: Visual Assessment

I. Inspection Checklist

Inspection Procedure	Post-Construction Visual Inspection
Timeframe	During maintenance period (1 – 2 years). Multiple site visits for sunny/rain conditions
Cost	low - staff time only
Level of Experience/Training	low to moderate
Metrics	Visual indicators
Target Objective	Determine if constructed to design plan, malfunctioning items of the practice and recommendations to fix or move to testing protocols found in level 2.

Inspection checklists are useful tools for ensuring complete reviews and recordkeeping. Checklists are useful at all stages of development from plan submission, plan review, construction, and maintenance. The following presents post-construction visual inspection checklist for certification and addressing functional and aesthetic problems. The post-construction visual inspection is not a replacement for inspections during construction. This testing protocol should be performed a week after constructing the LID practice and via multiple site visits during the warranty maintenance period. Parts of the inspection checklist require observations post rain event after 24 hours, during a rain event or on a sunny day.

A standard checklist along with an illustrated guide to the checklist is provided below. The illustrated guide allows inspectors with just a basic understanding of bioretention the ability to determine:

- what elements to inspect
- what qualifies as passing or as minor, moderate, or severe problems
- what actions should be taken based on the severity of the problems
- be consistent in evaluations between sites and other inspectors
- What are the follow-up actions required after remediating the problems

The following tools are recommended to have on hand:

- Safety: safety vests and as appropriate, other equipment such as traffic cones, signs/flags, confined space entry instruments, cell phone
- Flashing lights for road-side vehicle stops
- Digital Camera
- Dry erase board (to rapidly document site location and observations in photos)
- Dip-sticks (sediment)
- Manhole pick
- Various tools for opening observation wells (Flat screwdriver, hex wrenches, Phillips screwdriver, etc.)
- Shovel, rake
- Measuring tape
- Flashlight

BE SAFE
Use caution when entering or working around catch basins and manholes, and conform to confined space entry laws (Confined Spaces Regulation O. Reg. 632/05).
Most inspections can be performed above ground. If confined space entry is required, it is recommended that you contract with a qualified vendor with confined space entry experience.

- Soil auger
- Plant ID sheet
- Authorization letter
- Bug spray
- Design plans and as-built survey if available
- Appropriate checklists and reporting forms and reference charts/photos
- Soil moisture probe (to check vertical moisture profile if bioretention soil media clogging is suspected).

How to use checklist:

The most efficient way to inspect a bioretention practice is to focus on the individual zones as presented in the inspection checklist. These zones correspond with the checklist. The inspection starts with the drainage area and ends with the outlet. Perform inspections checklist on multiple visits throughout the maintenance period. Some questions on the checklist require established plant growth, sunny day observation, during a rain event, and post rain event to observe ponding more than 24 hours.

1. Identify which components on the checklist apply to your project using the design plans. The template bioretention checklist provides a comprehensive list of components that may apply to bioretention. Either check off the ones that apply or edit the template for the project.

2. Rate the condition of each relevant component. Refer to the numeric estimations or visual cues presented below in judging condition.

   1. If a defect or unsatisfactory conditions are found, then provide an explanation of the defect and recommended corrective action.
   2. List follow-up action after remediation has been done.

3. Sign under the certification section, certifying under penalty of perjury that the inspection has been performed, and either no corrective actions were identified or the work was completed as indicated.

For additional information on stormwater BMP inspection criteria and triggers for maintenance and rehabilitative actions, refer to

1. *Stormwater Assessment and Maintenance Book*. Erickson, Andrew; Gulliver, John; and Weiss, Peter. University of Minnesota in partnership with the Minnesota Pollution Control Agency. On-line manual: http://stormwaterbook.safl.umn.edu/

2. *Bioretention Illustrated: A Visual Guide for Constructing, Inspecting, Maintaining and Verifying the Bioretention Practice.* Lane, Cecilia; Scott, Ted and Schueler, Tom. 2013. Chesapeake Stormwater Network. Technical Bulletin #10. http://chesapeakestormwater.net/

3. King County Drainage Maintenance Standards for Commercial and Multifamily Drainage Facilities. King Count, Washington State. June 2008. http://www.kingcounty.gov/environment/waterandland/stormwater/documents/drainage-maintenance-standards.aspx

Site: ____________________________

Inspector: ____________________________

Date: ________________________________

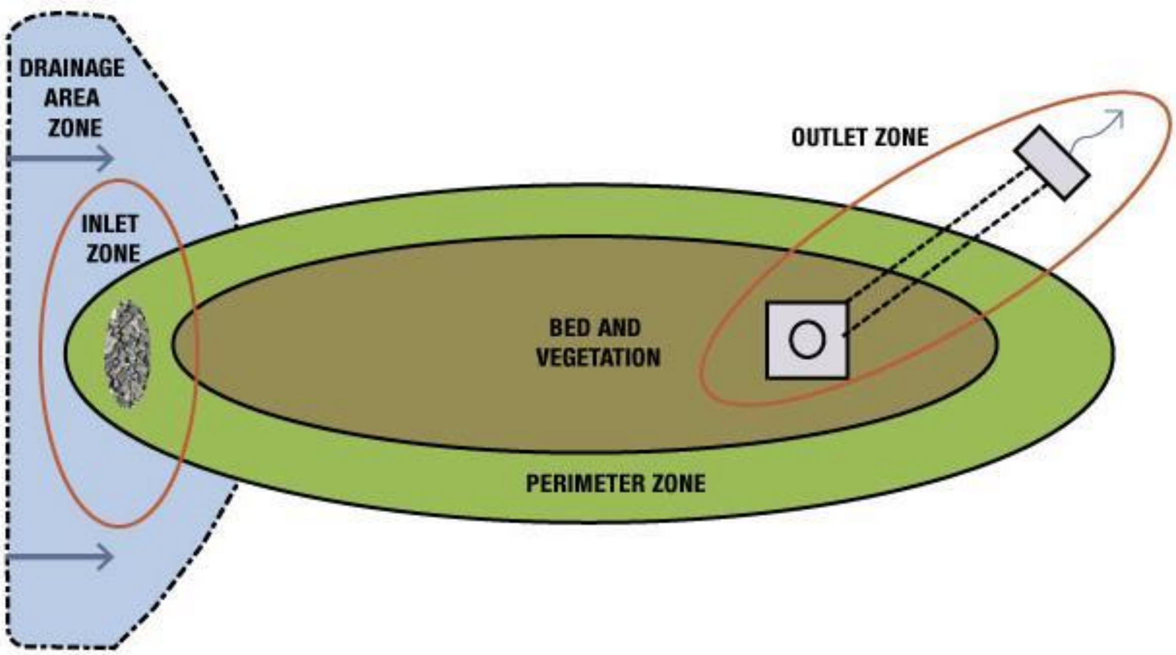
Item					Recommended Action	Follow up Test
Drainage Area Zone :						
1. Contributing Drainage Area	Pass	Minor	Moderate	Severe		
2. Drainage Area Trash/Debris	Pass	Minor	Moderate	Severe		
Inlet Zone:						
3. Inlet Obstruction	Pass	Minor	Moderate	Severe		
4. Inlet Erosion	Pass	Minor	Moderate	Severe		
5. Inlet Flow	Pass	Minor	Moderate	Severe		
6. Pre-treatment	Pass	Minor	Moderate	Severe		
7. Structural integrity	Pass	Minor	Moderate	Severe		
Perimeter Zone:						
8. Surface Area	Pass	Minor	Moderate	Severe		
9. Side Slope Erosion	Pass	Minor	Moderate	Severe		
Bed and Vegetation Zone :						
10. Bed Sinking	Pass	Minor	Moderate	Severe		
11. Sediment Accumulation	Pass	Minor	Moderate	Severe		
24HR 12. Standing Water	Pass	Minor	Moderate	Severe		
13. Ponding Depth	Pass	Minor	Moderate	Severe		
14. Mulch Depth/Condition	Pass	Minor	Moderate	Severe		
15. Bed Zone Trash/Debris Present	Pass	Minor	Moderate	Severe		
16. Bed Erosion	Pass	Minor	Moderate	Severe		
17. Bioretention Soil	Pass	Minor	Moderate	Severe		
18. Flow Distribution	Pass	Minor	Moderate	Severe		
19. Vegetation Cover	Pass	Minor	Moderate	Severe		

20.	Vegetation Health	Pass	Minor	Moderate	Severe
21.	Weeds or Invasive Species	Pass	Minor	Moderate	Severe
22.	Landscape Aesthetics	Pass	Minor	Moderate	Severe

Outlet Zone:

23.	Underdrains, Overflows	Pass	Minor	Moderate	Severe
24.	Outlet Obstruction	Pass	Minor	Moderate	Severe
25.	Outlet Structural Damage	Pass	Minor	Moderate	Severe

Use the inspection checklist legend to determine the condition of each zone.



Plan view of the bioretention inspection zones.

 Conduct test during sunny days

 Conduct test during rainy days

24HR Conduct Test 24-48 hours after rain event

#1	CONTRIBUTING DRAINAGE AREA

Description: This indicator determines whether the contributing drainage area matches the original design. Bioretention facilities that are undersized can lead to the need for more frequent maintenance and repairs. Estimate drainage area during a rain event using a video camera to record runoff flow, then compare to design drainage area.

PASS	**MINOR**
	
Contributing drainage area matches design drawings.	*Contributing drainage area is 5-10% different from design.*
MODERATE	**SEVERE**
	
Contributing drainage area is 10-25% different from design.	*Contributing drainage area is >25% different from design.*

	CORRECTION TRIGGER	RECOMMENDED ACTION
PASS	Contributing drainage area matches design	None
MINOR	Contributing drainage area is 5-10% different from design.	Note on inspection record.
MODERATE	Contributing drainage area is 10-25% different from design.	Designer must confirm that the practice will function properly with the larger or smaller drainage area. **Follow up test -** level 2: (as-built survey and infiltration test to confirm functionality)
SEVERE	Contributing drainage area is >25% different from design.	As-built survey should be completed. The designer must evaluate what adjustments to the drainage area or size of the practice need to be made. **Follow up test -** level 2: (as-built survey and infiltration test to confirm functionality after adjustments been implemented)

#2	DRAINAGE AREA TRASH/DEBRIS

Description: This indicator determines if the contributing drainage area is littered with trash and organic debris. Trash and debris can block important parts of the bioretention like the inlets and outlets as well as take up valuable storage area.

PASS	MINOR
	
No evidence of trash and debris	*Few pieces of trash and some organic debris*
MODERATE	**SEVERE**
	
Noticeable trash and debris accumulation	*High trash and debris load is impacting bioretention area.*

	CORRECTION TRIGGER	RECOMMENDED ACTION
PASS	Free of trash	None
MINOR	Few pieces of trash present	Note on inspection record and inform owner of maintenance responsibility to remove trash and debris.
MODERATE	Many pieces of trash accumulating	Evaluate surrounding area to see if there are any prevention opportunities (trash cans, tree trimming etc.).
SEVERE	Amount of trash is now negatively impacting the performance and function of the bioretention area.	Have trash and debris removed from the practice and drainage area. Evaluate surrounding area to see if there are any prevention opportunities (trash cans, tree trimming etc.). May require trash racks or other pretreatment practices to collect trash.

#3	INLET OBSTRUCTION

Description: Investigate the inlet for sediment, debris or turf that obstructs runoff from getting into the bioretention area, as well as proper grading that matches the design.

PASS	**MINOR**
	
This inlet is clean and in good condition.	*There is a minor amount of sediment and/or debris build up at the inlet.*
MODERATE	**SEVERE**
	
The moderate amount of sediment accumulation and weed growth indicates an entry problem that could lead to a risk of blockage.	*Sediment build-up or staining indicates that water is ponding and a significant amount of runoff is not getting into the facility.*

	CORRECTION TRIGGER	RECOMMENDED ACTION
PASS	Free of sediment/debris	None
MINOR	Less than 25mm of sediment and debris potentially blocking inlet	Note on inspection record and inform owner of maintenance responsibility to remove sediment from inlets.
MODERATE	25-75mm of sediment and debris blocking the inlet	Evaluate & address any blockages or grading problems causing excessive sediment buildup and flow bypass.
SEVERE	75 mm or more of blockage preventing most storms from getting into the bioretention area	Blockage or grading issues must be addressed before practice is accepted. **Follow up test -** level 2: (as-built survey to confirm functionality of positive drainage to the inlet without bypass or sediment inflow)

#4	INLET EROSION

Description: Investigate the inlet for evidence of channelized erosion or scour. This indicates improper elevations or a preferential flow path within the facility.

PASS

Inlet is in good condition, no evidence of erosion.

MINOR

Surface runoff from parking lot is causing minor erosion of mulch at inlet.

MODERATE

Concentrated flow results in moderate erosion at inlet. Investigation into cause is necessary as could result in more severe condition.

SEVERE

Scour is occurring at the inlet indicates a possible design flaw.

	CORRECTION TRIGGER	RECOMMENDED ACTION
PASS	No evidence of erosion at inlet.	None
MINOR	75– 150mm width of gully erosion	Rake, mulch and replace media
MODERATE	150– 300mm width of gully erosion	Schedule visit to stabilize inlet with fabric, stone or other erosion control.
SEVERE	More than 300mm width of gully erosion	Evaluate whether flow can be redistributed to other inlets or if a sediment forebay and flow spreaders are needed. **Follow up test -** level 2: (as-built survey to confirm functionality of positive drainage to the inlet without high slope. Also Rainy day video may provide needed information to better assess inlet flow.

#5	INLET FLOW

Description: During a rain event, this indicator evaluates whether water is flowing adequately into the bioretention cell.

PASS	MINOR
	
Water easily enters.	*Some bypass*
MODERATE	**SEVERE**
	
Most of water is bypassing.	*Water is completely bypassing the bioretention cell*

	CORRECTION TRIGGER	RECOMMENDED ACTION
PASS	Water is able to easily enter the bioretention cell.	None
MINOR	Water is slightly impeded from entering the bioretention cell. Some bypass is occurring.	Clear obstruction.
MODERATE	Water is impeded from entering the bioretention cell however some water is still able to enter.	Modify inlet structure
SEVERE	Water is completely bypassing the bioretention cell	Change and replace inlet structure with new design.

#6	# PRETREATMENT

Description: This indicator evaluates whether pre-treatment exists at the facility and whether it needs to be cleaned out. Pre-treatment is necessary to trap sediment and debris before it reaches and clogs the filter bed. Pre-treatment methods vary by bioretention design but the visual indicators approach would be similar for all.

PASS	**MINOR**
	
This pretreatment measure is free and clear of sediment/debris.	*Slight accumulation of sediment in the pretreatment cell.*
MODERATE	**SEVERE**
	
Pretreatment measures needed at this facility. Sediment deposition has almost entirely clogged the inlet.	*Lack of pretreatment or inadequate pretreatment has led to facility failure.*

	CORRECTION TRIGGER	RECOMMENDED ACTION
PASS	Free and clear of sediment or debris	None
MINOR	Pretreatment capacity is within 10% of design.	Remove and dispose sediment from pretreatment cell.
MODERATE	As much as 50% pretreatment capacity has been lost or no pretreatment provided.	Schedule visit to restore /create pretreatment capacity.
SEVERE	Loss of pretreatment capacity (or absence of pretreatment) is compromising facility.	Appropriate pretreatment needs to be added and any restoration to filter bed made. Need to remove sediment until biomedia is reached. **Follow up test -** level 2: (Infiltration test and soil test).

#7	# STRUCTURAL INTEGRITY

Description: This indicator assesses whether the facility is causing damage to adjacent pavement and curbs. Flows, scour or water seepage are usually the cause of the damage.

PASS	**MINOR**
	
Surrounding curbs and pavement are in good condition.	*Some pavement cracking occurring in surrounding pavement.*
MODERATE	**SEVERE**
	
Inlet elevation drop too steep leading to erosion within the facility. Reinforcement needed immediately to prevent collapse.	*Major problems with adjacent curbs and/or pavement. Design repair needed.*

	CORRECTION TRIGGER	**RECOMMENDED ACTION**
PASS	Surrounding curbs and pavement in good condition	None
MINOR	A few cracks or isolated deterioration but does not impair facility or infrastructure function	Note on inspection record.
MODERATE	Moderate flaws in structural integrity that are resulting in the facility not functioning properly.	Schedule visit to assess and develop repair strategy. Rain day video may help assess the causes.
SEVERE	Curbs or pavement are damaged and impairing function.	Schedule a visit by project estimator or contractor to conduct repairs. Rain day video may help assess the causes.

#8	SURFACE AREA

Description: This indicator determines whether the bioretention facility matches the original surface area of the design. Bioretention facilities that are undersized can lead to the need for more frequent maintenance and repairs. Use a measuring tape to estimate the facility area and compare to design area.

PASS

Constructed bioretention surface area matches design.

MINOR

Constructed bioretention surface area is 5-10% different than design (outline).

MODERATE

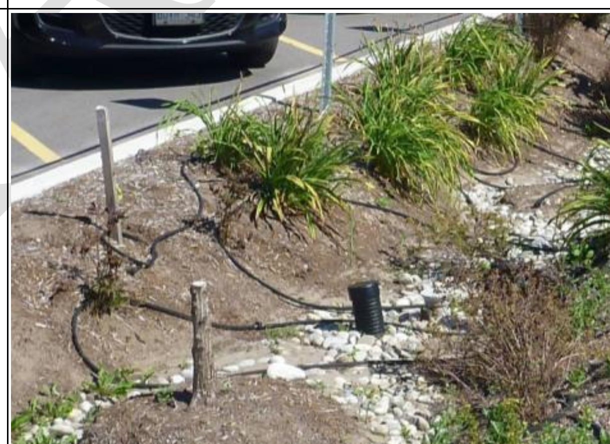
Constructed bioretention surface area is 10-25% different than design (outline).

SEVERE

Constructed bioretention surface area is over 25% different than design (outline).

	CORRECTION TRIGGER	RECOMMENDED ACTION
PASS	Surface area matches design	None
MINOR	Surface area 5-10% different from design	Note on inspection record.
MODERATE	Surface area 10-25% different from design	Designer must confirm that the practice will function properly with smaller surface area or direct the practice to be enlarged.
SEVERE	Surface area >25% different from design	Conduct analysis to see if surface area can be increased. Designer must confirm that the practice will function properly with smaller surface area.

#9	# SIDE SLOPE EROSION
Description: This indicator evaluates the stability of the side slopes of the bioretention area which should be 3:1 or flatter. Erosion of the side slopes can indicate a problem with grading or incoming runoff velocities and may require better inflow protection measures.	

PASS	**MINOR**
	
There is no evidence of side slope erosion occurring in this bioretention.	*There is minor side slope erosion occurring as a result of overland flow of water into the bioretention facility.*
MODERATE	**SEVERE**
	
The side slopes in this bioretention are too steep which is causing moderate erosion.	*Severe side slope erosion is occurring.*

	CORRECTION TRIGGER	**RECOMMENDED ACTION**
PASS	No evidence of side slope erosion.	None
MINOR	Isolated rill erosion, less than 25mm	Spot soil replacement and reseeding.
MODERATE	Gully erosion of 75mm or less at several points on the slope	Schedule visit to fill gullies (and replant, stabilize), add inflow protection measures.
SEVERE	Gully erosion greater than 75mm at any point	Investigate whether the gullies are formed by too much runoff and investigate slope reinforcement options and hardening. Remove any sediment that has made its way into facility.

#10	# BED SINKING

Description: This indicator determines whether any localized depressions or sink holes are present within the bed of the bioretention facility. This could indicate potential underground problems with the soil media, filter cloth, the stone layer and/or underdrain.

PASS	**MINOR**
	
Even, flat bed, with no evidence of sinking	*Minor, localized sinking occurring, likely cause is settling of the bioretention soil.*
MODERATE	**SEVERE**
	
Moderate, localized sinking occurring	*Severe sinking occurring at overflow structure.*

	CORRECTION TRIGGER	**RECOMMENDED ACTION**
PASS	Bed is even with no depressions	None
MINOR	75-150mm depth of localized bed sinking and no sediments observed in underdrain	Provide spot mulch and/or media refills, rake level.
MODERATE	150-300mm depth of localized bed sinking and no sediments observed in underdrain	Schedule second visit to fill in depressions with mulch and/or media, and replant.
SEVERE	>300mm depth of localized bed sinking and/ or sediments observed in underdrain	Check underdrain/overflow for media/soil, and/or conduct test pit near the holes. Soil may be escaping into the underdrain or an unsealed outlet structure. **Follow up test - level 2:** (Synthetic runoff test).

#11	SEDIMENT ACCUMULATION

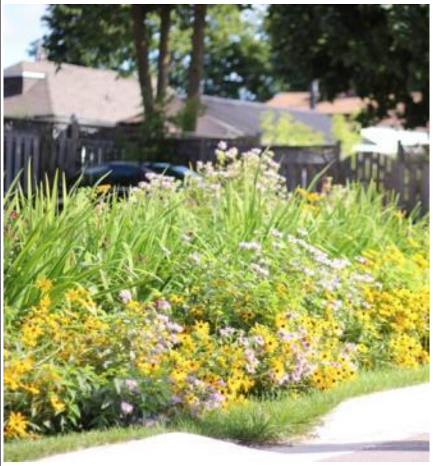
Description: This indicator determines if sediment caking or deposits exist in the bed that could impair the performance of the facility. This could indicate a source of sediment in the contributing drainage area or problems with the pre-treatment measures.

PASS	MINOR
	
Bioretention in good condition. Free of sediment and caking.	*Thin and isolated areas of sedimentation caking.*
MODERATE	**SEVERE**
	
Thin but widespread sedimentation occurring.	*Severe sedimentation occurring; bioretention most likely clogged.*

	CORRECTION TRIGGER	RECOMMENDED ACTION
PASS	No evidence of sediment or caking on the bioretention bed	None
MINOR	<25mm of sedimentation or caking occurring within the facility	Rake and remove surface sediment accumulation.
MODERATE	25-50mm of sediment deposition occurring within the facility	Remove sediments and check pretreatment and contributing drainage area for sediment sources. **Follow up test -** level 2: (Infiltration test and soil test).
SEVERE	More than 50mm of deposition in the facility	Conduct full cleanout to depth of 150mm within bed surface. Identify and fix sediment delivery problem. **Follow up test -** level 2: (Infiltration test and soil test).

#12	STANDING WATER	24HR

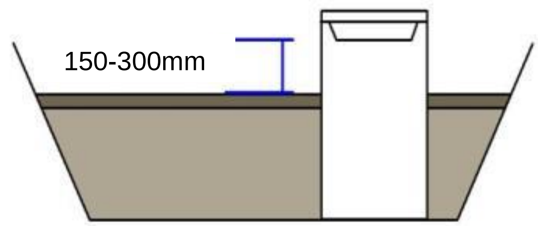
Description: This indicator determines if the bioretention facility is functioning properly. Bioretention facilities are designed to be free of standing water 24 hours after the end of a storm event. Standing water or evidence thereof indicates a problem within the facility.

PASS	MINOR
	
Bioretention in good condition, no evidence of standing water.	*Saturated soils indicate presence of standing water.*
MODERATE	**SEVERE**
	
Isolated areas of shallow standing water 24 hours after the end of an event.	*Widespread standing water for more than 24 hours after the end of an event indicates facility failure.*

	CORRECTION TRIGGER	RECOMMENDED ACTION
PASS	No evidence of standing water	None.
MINOR	Saturated soils or evidence of obligate wetland plant species	Make a note, and check for at next maintenance visit.
MODERATE	25-75mm of standing water after 24 hrs	Note as a potential risk for failure and schedule for more frequent inspection.
SEVERE	>75mm of standing water after 24 hrs	Pump down, dig test pit, replace soil, and check for clogged geotextile fabrics. **Follow up test -** level 2: (Infiltration test and soil test).

#13	# PONDING DEPTH

Description: This indicator determines whether the current ponding volume of the bioretention facility matches the design. Ponding areas that are too shallow are an indication that the bioretention does not provide the correct amount of storage whereas ponding areas that are too deep cause a safety and performance problem. If there is no overflow pipe, run string line from outfall and measure to base of swale.

PASS	**MINOR**
	
Ponding depth should be measured and compared to the original design. 150-300mm is standard for most bioretention facilities.	
MODERATE	**SEVERE**
	
The ponding depth of this facility is significantly shallower than originally designed.	*The ponding depth of this facility is significantly deeper than originally designed.*

	CORRECTION TRIGGER	**RECOMMENDED ACTION**
PASS	Ponding depth matches design.	None
MINOR	Less than 10% departure from design ponding depth	Note in project file.
MODERATE	Plus or minus 100mm departure from design ponding depth	Remove mulch/media if too shallow; Add mulch/media if too deep. Re-measure ponding depth.
SEVERE	More than 25% departure from design	Find a solution to address issue and correct height to match design. . Re-measure ponding depth.

#14	MULCH DEPTH/CONDITION

Description: This indicator assesses the mulch depth and condition in the bioretention area which should be 50-75mm deep unless the bed has significant ground cover (>75%). This visual indicator also assesses that there is not too much mulch in the facility which could lead to nutrient leaching, the loss of ponding depth, or smothering plant roots.

PASS	MINOR
	
Bioretention in good condition. Good mulch depth and/or ground cover.	*Slight displacement occurring. Add mulch and/or ground cover.*
MODERATE	**SEVERE**
	
Level of mulch is blocking curb inlet.	*10" of mulch indicates maintenance crew not aware of function of facility.*

	CORRECTION TRIGGER	RECOMMENDED ACTION
PASS	50-75mm of mulch and more than 75% vegetative cover	None
MINOR	25mm or less of mulch or 65% ground cover	Schedule mulching for next visit.
MODERATE	100-125mm of mulch or no mulch and less than 50% vegetative cover	Add or remove mulch to design depth and add more ground cover to meet passing grade.
SEVERE	More than 150mm of mulch or no mulch and < 35% vegetative cover	Add or remove mulch to design depth and add more ground cover to meet passing grade.

#15	# BED ZONE TRASH/DEBRIS

Description: This indicator determines if the bioretention is filled with trash and organic debris and needs to be cleaned out. Trash and debris can block important parts of the bioretention like the inlets and outlets as well as take up valuable storage area.

PASS	**MINOR**
	
No trash in bed area	*Some trash and organic debris in bed area*
MODERATE	**SEVERE**
	
Significant trash and organic debris in bed area	*Significant trash and organic debris in bed area negatively is affecting performance.*

	CORRECTION TRIGGER	RECOMMENDED ACTION
PASS	Free of trash	None
MINOR	Significant amount of trash	Remove trash and debris and dispose of appropriately.
MODERATE	Three major cleanouts a year	Evaluate drainage and surrounding area to see if there are any prevention
SEVERE	More than three major cleanouts a year	Evaluate drainage and surrounding area to see if there are any prevention opportunities (trash cans etc.).

#16	BED EROSION
Description: This indicator determines whether erosion is occurring in what should be a flat bed facility. Bed erosion can be a sign of an undersized facility either due to poor design or changes in its drainage area.	

PASS	**MINOR**
	
Bioretention is in good condition – no bed erosion occurring.	*Minor bed erosion or displacement is occurring as a result of a larger storm event.*
MODERATE	**SEVERE**
	
Significant bed erosion is occurring leading to a preferential flow path.	*Severe bed erosion demonstrates that the bioretention may be undersized for the volume of runoff it is receiving or inadequate flow spreading throughout the facility.*

	CORRECTION TRIGGER	**RECOMMENDED ACTION**
PASS	Bed is flat and even	None
MINOR	75-150mm of rill erosion	Backfill with soil and cover, add mulch and rake.
MODERATE	150-300mm of gully erosion	Schedule visit to install measures to disperse flows more evenly, rake, backfill and mulch.
SEVERE	>300mm of gully erosion	Designer must confirm sizing and flow paths are correct. Regrading and dispersal measures like stone channels may be necessary. **Follow up test -** level 2: (As-built survey).

#17	# FLOW DISTRIBUTION

PASS	MINOR
	
Water is evenly distributed throughout bioretention cell.	
MODERATE	**SEVERE**
	

	CORRECTION TRIGGER	RECOMMENDED ACTION
PASS	Water is evenly distributed throughout bioretention cell.	None.
MINOR	Water is distributed at least half of the bioretention cell	Fine grade bioretention media and mulch to allow for positive drainage
MODERATE	Most of the water is concentrated at one end of the bioretention cell	Regrade bioretention cell to allow for positive drainage
SEVERE	Water is not being distributed to parts of the bioretention cell.	Regrade bioretention cell to allow for positive drainage

#18	# BIORETENTION SOIL	
Description: This indicator determines whether the soil meets design specification and has good drainage rates while still able to support vegetation. If soil does not meet specifications corrective actions must take place immediately.		

PASS	**MINOR**
	
Soil has a high sand content to allow for quick infiltration of water.	*Soil is sandy but has clumps. Some clumps may be organic matter, but others could contain clay.*
MODERATE	**SEVERE**
	
Soil is cohesive or sticking together when wet and there are signs that the practice is not draining quickly.	*Soil has a high clay content which holds water and has a very slow infiltration rate.*

	CORRECTION TRIGGER	**RECOMMENDED ACTION**
PASS	Visually inspect soil to ensure there is a high sand content to allow for infiltration. Soil should be loose and sandy.	None
MINOR	Soil might have clumps forming due to fines and clay present in soil mixture.	If there are many clayey clumps throughout the soil a sample should be sent to a lab for inspection of particle size distribution to see if it meets specifications. **Follow up test -** level 2: (soil test)
MODERATE	Soil will have many clumps and is slow to drain. Could hold more water and remain saturated for longer periods of time.	Soil sample should be collected for analysis. If soil has a high content of clay and/or fines it may have to be replaced. **Follow up test -** level 2: (soil test)
SEVERE	Soil does not drain and is very sticky and clumpy due to high clay content.	Soil will need to be removed and replaced with a new batch of approved soil. **Follow up test -** level 2: (soil test)

#19	VEGETATION COVER

Description: This indicator determines whether the facility is achieving the desired percentage of vegetation cover. Adequate vegetative cover is critical to reduce runoff and pollutants in a facility. Lack of vegetation can impair the pollutant uptake function of a bioretention area, reduce infiltration capacity over time and result in maintenance issues like erosion. This indicator can only be assessed during the growing season.

PASS	MINOR
	
This bioretention has good vegetative cover.	*This bioretention has a few bare spots and could use spot planting.*
MODERATE	**SEVERE**
	
This bioretention has less than 75% vegetative coverage and is probably not functioning to its full potential.	*Vegetation is not growing in this bioretention as a result of it not being an environment conducive to vegetation or poor maintenance is occurring.*

	CORRECTION TRIGGER	RECOMMENDED ACTION
PASS	Good vegetative cover, >75%	None
MINOR	Isolated bare spots (< 65% vegetative cover)	Split herbaceous materials, reseed, and add reinforcement plantings.
MODERATE	< 50% vegetative cover	Replant, schedule visit to do a major replanting. **Follow up test -** level 2: (soil test)
SEVERE	< 35% vegetative cover	Investigate cause of plant mortality. Based on findings, design a revised planting plan for facility. **Follow up test -** level 2: (soil test)

#20	# VEGETATION HEALTH

Description: This indicator assesses the health of the vegetation planted in the bioretention facility. Plants should be healthy and alive and match the original planting plan.

PASS	**MINOR**
	
>80% of plants are thriving, and <5% are dead or diseased.	*5-20% of plants are dead or diseased.*
MODERATE	**SEVERE**
	
20-60 % of plants are dead or diseased.	*Over 60% of the plants are dead or diseased.*

	CORRECTION TRIGGER	RECOMMENDED ACTION
PASS	Plants alive and in good condition (>80% of plants are thriving, <5% dead plants)	None
MINOR	5-20% of plants are dead or diseased.	Weed and replant.
MODERATE	20-60 % of plants are dead or diseased.	Determine the cause of plant mortality, replant.
SEVERE	Over 60% of the plants are dead or diseased. Significant plant mortality and/or takeover by invasive species. The objectives of the original planting plan are no longer being met.	Replant garden with new planting plan.

#21	WEEDS AND INVASIVE SPECIES	

Description: This indicator assesses if weeding is required. Regular maintenance should be performed regularly to avoid an overgrowth of weeds or invasive plants.

PASS	**MINOR**
	
No visible weeds or invasive plants	*Spot weeding needed.*
MODERATE	**SEVERE**
	
Moderate weeding required.	*This bioretention is overrun with invasive plants and weeds.*

	CORRECTION TRIGGER	**RECOMMENDED ACTION**
PASS	No visible weeds or invasive species.	None.
MINOR	Considerable weeding needed	Weed as needed.
MODERATE	Moderate weeding required.	Weed as needed and try to establish a regular schedule. Use the Bioretention Vegetation Assessment tool to help identify appropriate replacements.
SEVERE	Bioretention is overrun with weeds and invasive species that need to be removed immediately.	Remove weeds and invasive plants and try to determine cause of growth. Maintain site regularly. Use the Bioretention Vegetation Assessment tool to help identify appropriate replacements.

#22 LANDSCAPE AESTHETICS

Description: This indicator assesses what level of vegetative maintenance is occurring at the bioretention area to maintain its function and appearance. The level of maintenance a bioretention facility receives depends largely upon its landscaping design and owner expectations for landscape appearance.

PASS	MINOR
	
Well-maintained and meets aesthetic standard.	*Well-maintained. Plant bares spots.*
MODERATE	**SEVERE**
	
Overgrown vegetation, removal needed.	

	CORRECTION TRIGGER	RECOMMENDED ACTION
PASS	Vegetation is being maintained per its landscaping objective.	None
MINOR	Bioretention is getting a bit bushy, needs some weeding or thinning.	Plant bares spots.
MODERATE	Overgrown vegetation, removal needed	Monitor planting or schedule removal of planting.
SEVERE	Overgrown vegetation, removal needed	Schedule removal of planting.

#23 UNDERDRAINS, OVERFLOWS

Description: This indicator assesses whether the outlets, underdrains and/or overflows are clean, free of obstructions and are working properly. If the outflow device has sediment or debris in it, this is a sign of a more serious problem occurring within the facility. Outlets and cleanout standpipes can be opened and visually checked for sediment buildup and clogging. If available, special pipeline video camera equipment can be used to inspect the underdrain pipes.

PASS

This underdrain is mainly free of sediment and debris.

MODERATE

This underdrain is clogged with sediment. Further investigation is needed to determine the cause of the problem.

	CORRECTION TRIGGER	RECOMMENDED ACTION
PASS	Outflow device is free of sediment and debris	None
MINOR	Nominal loss of pipe capacity	Flag to investigate during next inspection cycle
MODERATE	Significant loss of pipe capacity	Cleanout pipe and investigate cause.
SEVERE	Outflow device is completely clogged with sediment or debris	Cleanout pipe immediately and investigate cause, repair or replace pipe.

#24	OUTLET OBSTRUCTION

Description: This indicator assesses whether the outlet is clean, free of obstructions and is working properly. If the outflow device has sediment or debris in it, this is a sign of a more serious problem occurring within the facility.

PASS	MINOR
	
Outlet is clear and able to accept overflow.	*Outlet is partially blocked, but still able to accept overflow.*
MODERATE	**SEVERE**
	
Outlet is covered but location is still visible.	*Outlet is completely covered and could not be located under debris. Overflow could not enter.*

	CORRECTION TRIGGER	RECOMMENDED ACTION
PASS	Outlet is free of debris and can accept overflow.	None
MINOR	Outlet is partially blocked, but still able to accept overflow.	Clear off debris and note the potential ongoing maintenance issue.
MODERATE	Outlet is covered but location is still visible.	Clear off debris and investigate and implement options to reduce debris sources or screen debris from collecting on the overflow outlet.
SEVERE	Outlet is completely covered and could not be located under debris. Overflow could not enter.	Clear off debris and investigate and implement options to reduce debris sources or screen debris from collecting on overflow outlet. The severity of the problem may indicate other problems like incorrect mulch or overflow height.

#25	OUTLET STRUCTURAL DAMAGE	
Description: This indicator assesses whether the outlet has any structural damage and if its function is being compromised.		

PASS	MINOR
	
Outlet is present and in good working condition	*Outlet is partially damaged, but still able to prevent debris from entering.*
MODERATE	**SEVERE**
	
Outlet is damaged and should be replaced to prevent debris from entering.	*Outlet is completely missing, should be replaced immediately.*

	CORRECTION TRIGGER	RECOMMENDED ACTION
PASS	Outlet is present and in good working condition.	None
MINOR	Outlet is partially damaged, but still able to prevent debris from entering.	Outlet should be replaced before further damage takes place and debris enters underdrain.
MODERATE	Outlet is damaged and should be replaced to prevent debris from entering.	Outlet should be repaired or replaced immediately.
SEVERE	Outlet is completely missing, should be replaced immediately.	Outlet should be repaired or replaced immediately.

II. Photo and Video Documentation

It is important to document site conditions throughout the project through qualitative observations. Qualitative observations can include photographing and videotaping. Prior to construction, consider photographing and videoing flow patterns during rain events, which can provide an overview of the initial site conditions. Recording runoff and rainfall can also provide insight on the volume of water that the LID practices should be designed to treat.

During construction photographs and videos may provide information that can be used to make alterations to the design or monitoring plan. This can also be useful in determining if erosion and sediment controls are being used properly to avoid clogging or damaging infiltration areas which can affect performance.

Drainage or catchment areas should be evaluated once a site has been constructed and periodically throughout the monitoring program. This can be completed by conducting detailed survey, videotaping flow patterns during rain events, and installing cameras to capture continuous images. Often these qualitative observations will provide insight into the functionality of the site that may not become apparent even with detailed monitoring.

Some observations that can be made from precipitation videos and continuous photos include:

- Issues with bypass where water does not enter inlets as expected during various event intensities
- Ponding of water in/on LID practices during rain events
- Observations of plant growth and health over various seasons

Still image from a video of water flowing into an inlet catchbasin during a rain event

A photo log should be maintained from all site visits. This is an important and useful tool to monitor the progression of the site over time for maintenance as well as plant growth and health. Monitoring a site can help determine which plants should or should not be used and which combinations work best for various LID practices. Having images of the site are important to document any changes that may be experienced with large or intense rainfall events including sediment deposition or displacement, debris or mulch removal.

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Photos from a trail camera installed in a bioretention showing seasonal variations

III. Vegetation Survey

Inspection Procedure	Vegetation Survey
Timeframe	Can complete in 2-4 hours, perform early summer and early fall, may last 1-3 years if monitoring throughout establishment
Cost	moderate
Level of Experience/Training	moderate to high
Metrics	Plant health and survival
Target Objectives	Replacement of dead plants before certification

The vegetation survey protocol is a tool for bringing vegetation to full establishment before certification. It is a tool for the inspector at the time of certification, as a one-time use and for the contractor or project manager to use throughout the warranty and establishment period as an iterative process. It will also help the property owner choose suitable replacements for plants that have died or that are not doing well as part of adaptive management.

The following protocol helps property owners take over a landscaped LID practice after the construction and warranty period are over. The plants will usually be covered under warranty for one or two years. The property owner should make sure that the plants are doing well at least once before the warranty expires so that the contractor can replace them if necessary. It is important to make sure that plants are healthy so that:

- The property owner doesn't have to spend more money than needed
- The bioretention cell looks good
- The bioretention cell will continue to perform into the future

Once the vegetation survey passes the protocol the owner can shift to post-establishment maintenance.

The purpose of the vegetation survey is to determine which plants need to be replaced and what they should be replaced with. The first step is to bring the original plant list, planting plan or nursery receipts and find those plants in the garden. Usually, after a few summers the plants will not match the original planting plan. Some of the original plants will do really well, some will die, and others will have moved in from somewhere else. Also note how well each species did as a whole. If some of the plants have died, consider replacing them with species that have done really well.

Plant Health Rating

5. Doing really well	4. Doing well	3. Doing OK	2. Not doing well	1. Dead/Missing
				

Table 4 Example Vegetation Tally

Species	**Original Number (see plant list)**	**Count**	**Plant Health Rating**	**Notes**
Trees				
Red maple	4	4	5	
Shrubs				
Ninebark	8	4	2	
Hydrangea	8	6	4	
Perennials				
Black-eyed Susan	20	20	5	
Blue flag iris	10	6	3	
Bee balm	20	15	4	

IV. Sediment Monitoring

Prior to transfer of ownership, the site should be assessed for sediment in the conveyance system. Any accumulations should be removed prior to transfer of ownership. Secondly, all maintenance schedules should be conveyed to the property owner.

Inspection Procedure	Sedimentation monitoring
Timeframe	Can complete in 15 min or less, perform every 3 months, 1-2 years are needed to establish a maintenance schedule
Cost	minimal
Level of Experience/Training	moderate
Metrics	sediment levels
Target Objectives	1. No sediment or debris prior to certification 2. Define a maintenance schedule for the property owner or maintenance staff (must be performed on a regular basis (typically monthly) for 1-2 years.

All stormwater practice will collect sediment. To extend the life of bioretention and other infiltrating practices, good housekeeping practices should be employed in the drainage areas. These housekeeping practices include stabilizing with vegetation or pavement all areas of bare soil, regular sweeping, and proper material storage practice. Pretreatment practices will also help extend the life of an infiltration practice: these include catch basin sumps, splash pads and sedimentation forebays. In addition, sediment levels within pretreatment practices should be measured and recorded every 3 months. These observations will be used to schedule cleanouts of the pretreatment practice.

Proper material stockpiling practice in a bioretention planter drainage area.

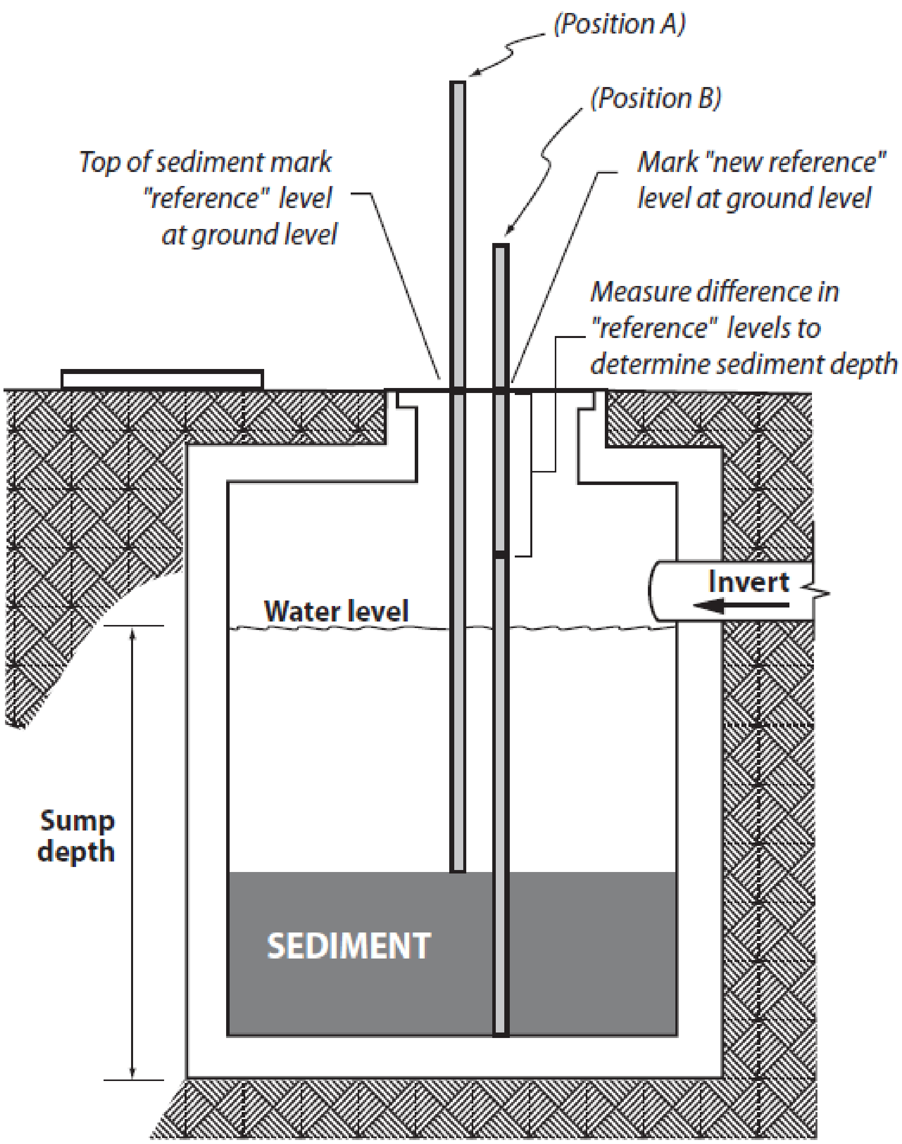
Below are simplified instructions on checking the sediment level in a typical catch basin or sedimentation forebay:[6]

1. Remove the manhole cover/grate using a 1/2–inch Allen wrench and a catch basin grate hook or crow bar.

2. Identify the sump depth (water level).
Using a probe or rod, identify the sump depth. This is done by inserting the rod through the water and sediment until it hits the bottom of the catch basin; water level will be visible for measurement upon removal. *NOTE: Under normal conditions, the water level should be even with the outlet pipe. A higher water level indicates a blockage in the outlet.*

3. Identify the sediment level.
a) Put the probe or rod in through the water until it touches the top of the sediment. Mark it with relation to a stationary point in the catch basin with tape or chalk (Position A).
b) Put the probe or rod in through the water and sediment until it touches the bottom of the catch basin, and mark the probe with relation to the same stationary point as in item a above (Position B).
The difference between the two marks is the **sediment depth**.
c) The water mark left on the rod is the "sump depth." Measure the ratio of sediment depth to sump depth to determine allowable amounts.

[6] Adapted from the *King County Drainage Maintenance Standards* booklet



Measuring sediment depths. (Source: King County Drainage Maintenance Standards)

If the sediment level is at 60% of the full capacity, then it should be immediately removed. Entering the structure should not be necessary. Only staff or consultants with confined space training in accordance with *Confined Spaces Regulation (O. Reg. 632/05)* should enter stormwater structures.

Level 2: Capacity Testing

I. Soil Testing

Inspection Procedure	Soil Testing
Timeframe	1- 2 weeks for analysis to be completed
Cost	moderate $200 - 500
Level of Experience/Training	moderate to high
Metrics	grain size, pH, organic content, cation exchange capacity
Target Objectives	The infiltration characteristics of a soil are directly related to the hydraulic conductivity and the porosity of the soil, and these in turn are affected by soil texture and the bulk density (Hillel, 1998). Soil properties such as porosity and hydraulic conductivity can change over time affecting infiltration – both positively or negatively. The following targets were pulled the Low Impact Development Construction Guide. Texture: *Coarse to Medium Sand (2.0 – 0.25 mm dia.): 71 - 92 % by weight Fine Sand (0.25 – 0.05 mm): 0 – 17 % by weight Silt and Clay (< 0.05mm dia. or sieve 270): 8- 12 % by weight *The majority of the sand component should be coarse to medium sand; only up to 17% of the mix can be fine sand. The mixture should be free of stones, stumps, roots, or other similar objects larger than 50 mm. 2. Organic content: 3- 5% by dry weight (supplied by leaf and yard compost or composted pine mulch) 3. Cationic exchange capacity (CEC): >10 meq/100 g. 4. pH: 5.5 - 7.5

Toronto Region Conservation Authority's document on "*Preserving and Restoring Healthy Soil: Best Practices for Urban Construction"* (2012) contains references to ASTM standards for testing soil grain size distribution (i.e.: texture), organic matter content, and pH. Testing methodologies for cationic exchange capacity should be ASTM D7503-10 Standard Method for Measuring the Exchange Complex and Cation Exchange Capacity of Inorganic Fine-Grained Soils.
1. Inspection of soil properties for visual inspection and all other monitoring levels (standard first step to be performed).

2. Texture
3. Bulk Density (Revised from ASTM, 2004) kg · m-3 (kg/m3)
4. Determination of Bulk Density of the Soil Sample (Revised from ASTM, 2004):
Simplified method http://soils.usda.gov/sqi/assessment/files/chpt4.pdf
http://www.icp-forests.org/pdf/Chapt_3a_2006(2).pdf

Soil bulk density is the ratio of the mass of dry solids to the bulk volume of the soil. The bulk volume includes the volume of the solids and the pore space. It is needed for converting water percentage by weight to content by volume. The mass is determined after drying to constant weight at 105 °C and the volume is that of the sample as taken in the field. It is also possible to use a microwave oven to achieve a constant dry weight.

There are four methods of determining the bulk density of soil: core method, clod method, excavation method, and radiation method. The determination usually consists of drying and weighing a soil sample, the volume of which is known (core method) or must be determined (clod method and excavation method). A different principle is employed in the radiation method. The core method (A.S.T.M. D 2937-04, 2004) is the most straightforward. This method is not recommended for use in organic or friable soils, and may not be applicable if the soil cannot be retained in the drive cylinder. Simple soil moisture content based on soil feel and appearance by soil texture (Farzana and Gulliver, 2012).

II. As-Built Survey

Inspection Procedure	Post-Construction As-Built
Timeframe	1/2 to 1 day
Cost	moderate
Level of Experience/Training	moderate to high
Metrics	elevations and areas
Target Objective	Areas and storage volumes match the design plan within acceptable tolerance.

1. Obtain municipal drainage maps with elevations of surrounding areas that may contribute to the bioretention practice.
2. Obtain site map from contractor with elevations noted for inlets, outlets, all design specifications including specification materials used and certified by developer.
3. A design characteristics table should be provided by the developer to the owner with appropriate values including critical elevations for each inlet, outlet, drain pipe, discharge elevation, and indication as to how much backwatering could occur during large/infrequent storm events.

Examples Bioretention Site Design Characteristics Table	
Contributing Drainage Area (m2)	
Bioretention Area (m2)	
Maximum Ponding Depth (m)	
Infiltration Rate (mm/hour)	
Drawdown Time (hrs)	
Bioretention Depth (m)	
Bioretention Volume (m3)	
Storage Capacity (design) m3	
Infiltration/Drawdown Time (hours)	

III. Infiltration Testing

Inspection Procedure	Infiltration Testing
Timeframe	Can complete in 30 min or less
Cost	minimal
Level of Experience/Training	moderate to high
Metrics	Visual indicator
Target Objective	infiltration rate, estimated drawdown times based on those rates

Infiltration Measurement Overview

At least 3-10 hydraulic conductivity measurements are recommended. Hydraulic conductivity measurements should be conducted during dry conditions preceded by 24 hours without precipitation. At least one measurement should be positioned over critical areas which are anticipated to be susceptible to clogging (typically areas near inlets for bioretention).

Infiltration characteristics of a bioretention site soils are related to the hydraulic conductivity and the porosity of the media, and these are affected, in turn, by soil texture and bulk density. Soil textures are a useful surrogate for estimating hydraulic conductivity or K_{sat} as shown in the below table from Farzana and Gulliver (2012) with the last column showing values in cm/second (below).

Two methods of commonly used infiltration monitoring employ the Double Ring infiltrometer or the Guelph Permeameter. Both will provide reasonable measures. In general, soils of all types, including engineered soils, will exhibit considerable variation in infiltration rates. When performing infiltration measurements, soil moisture is frequently measured by laboratory testing or by visual observations. In general, it has been found that the change in moisture content (pre and post infiltrometer monitoring) has a relatively minor (less than 20%) effect on saturated conductivity (Farzana and Gulliver citing Regelado et. al., 2005). Initial and post-test soil moisture values should be obtained or estimated by feeling the soil and by using the table provided below. Given large range of hydraulic conductivity to be expected on a site, soil moisture differences are relatively minor. As a general rule of thumb, 3-10 measurements should be obtained for smaller sites (e.g. less than 50 square meters) and the data should be summarized as a geometric mean +/- Coefficient of Variation (standard deviation divided by the mean).

Table 4. Typical measurements taken on soils. Two thirds of the measurements are within the values given in parenthesis.

Soil type	Porosity	Effective porosity	Capillary pressure (cm)	Hydraulic conductivity (cm/sec)
Sand	0.437 (0.374~0.5)	0.417 (0.354~0.48)	-4.95 (-0.97~-25.36)	$3.25*10^{-3}$
Loamy sand	0.437 (0.363~0.506)	0.401 (0.329~0.473)	-6.13 (-1.35~-27.94)	$8.3*10^{-4}$
Sandy loam	0.453 (0.351~0.555)	0.412 (0.283~0.541)	-11.01 (-2.67~-45.47)	$3*10^{-4}$
Loam	0.463 (0.375~0.551)	0.434 (0.334~0.534)	-8.89 (-1.33~-59.38)	$9.4*10^{-5}$
Silt loam	0.501 (0.42~0.582)	0.486 (0.394~0.578)	-16.68 (-2.92~-95.39)	$1.8*10^{-4}$
Sandy clay loam	0.398 (0.332~0.464)	0.33 (0.235~0.425)	-21.85 (-4.42~-108)	$4.2*10^{-5}$
Clay loam	0.464 (0.409~0.519)	0.309 (0.279~0.501)	-20.88 (-4.79~-91.1)	$2.8*10^{-5}$
Silty clay loam	0.471 (0.418~0.524)	0.432 (0.347~0.517)	-27.3 (-5.67~-131.5)	$2.8*10^{-5}$
Sandy clay	0.43 (0.37~0.49)	0.321 (0.207~0.435)	-23.9 (-4.08~-140.2)	$1.7*10^{-5}$
Silty clay	0.479 (0.425~0.533)	0.423 (0.334~0.512)	-29.22 (-6.13~-139.4)	$1.4*10^{-5}$
Clay	0.475 (0.427~0.523)	0.385 (0.269~0.501)	-31.63 (-6.39~-156.5)	$8.3*10^{-6}$

Porosity, effective porosity, capillary pressure and hydraulic conductivity for different soil textures (Farzana and Gulliver, 2012).

Measuring Field Saturated Hydraulic Conductivity, K_{sat}

As described by Gupta et. al., the saturated hydraulic conductivity (K_{sat}) is the most sensitive parameter for many hydrologic, drainage, and non-point source pollution models. Gupta at. el. performed a study that looked at many methods for measuring the in-situ hydraulic conductivity including the Double Ring infiltrometer (DRI) and constant-head Guelph Permeameter (GP). The main difference between these two methods is that the DRI is based on a one-dimensional flow theory whereas the GP is based on a 3-dimensional flow theory.

Double Ring Infiltrometer

Gupta et. al. described the double ring infiltrometer apparatus as such that it consists of two concentric metal rings of 30.5 and 60.5 cm of diameter. These rings are inserted into the field test area at a depth of 10 cm and water is poured into the rings while maintaining a constant head at the inner ring. The primary purpose of the outer ring is to prevent lateral movement of water beneath the inner ring and maintain a one-dimensional flow condition. As outlined by Gupta et. al., the cumulative infiltration is measured and recorded overtime which is then converted to the corresponding infiltration rate for the elapsed time from the start of each test. The Philips infiltration equation is then used to convert the infiltration data to K_{sat} using the follow equation:

$$I = At + ST^{1/2}$$

Where,
I = cumulative infiltration (cm)

A = parameter known as transmissivity factor (cm/min),
S = sorptivity (cm/min$^{1/2}$)
T = elapsed time since the start of infiltration (min)

As described by Gupta et. al., the parameter A reflects the steady-state infiltration rate in the wetting zone, whereas the parameter S has been interpreted to be the component of infiltration due to the vertical gradient in the soil matric potential in the early stages of infiltration. Both parameters are functionally related to the saturated hydraulic conductivity and these parameters can be determined by fitting the Philips equation to the experimental data obtained in the field. The A values were converted to K_{sat} estimates by using a multiple factor of 2/3[1]. To obtain a step by step procedure for the field testing and subsequent calculations, refer to the ASTM standard D3385.

Guelph Permeameter

Gupta et. al states that the Guelph permeameter (GP) is based on the assumption of a three-dimensional steady state infiltration from a cylindrical test hole in the unsaturated soil. The permeameter setup is described in great detail in the Operating Instructions Manual by Soil Moisture. In the manual, the permeameter is described to consist of an “in-hole Marriotte bottle” made of two concentric tubes. The inner “air-inlet” tube provides the air supply, and the outer tube serves as the water reservoir and as an outlet into the well. Water flows out of the outlet tube through a funnel-shaped perforated section located above the permeameter tip. Gupta et. al. state in their study that this equipment is used to measure the steady-state rate of water flow required to maintain a constant depth of water in a cylindrical test hole of about 15-30 cm.

Values of the steady-state flow, Q, are measured at two water level depths of H_1 = 5 cm and H_2 = 10 cm in each test hole and the following equation was used to calculate the saturated hydraulic conductivity and the matrix flux potential (Gupta et. al., 1993).

$$\boxed{Q = 2\pi H^2 \frac{K_{fs}}{C} + \pi a^2 K_{fs} + 2\pi H \frac{\varphi_m}{C}}$$

Where:

Q	= steady-state recharge (m^3/s),
H	= depth of water maintained in the auger hole (m),
A	= radius of cylindrical auger hole (m),
K_{fs}	= field saturated hydraulic conductivity (m/s),
C	= shape coefficient, and
φ m	= matric flux potential (m2/s)

For a detailed step by step procedure on how to perform the field test and perform the subsequent data analysis, refer to the Guelph Permeameter Operating Instructions provided by Soil moisture Equipment Inc (http://www.soilmoisture.com/pdf/82800k1.pdf).

The double ring infiltrometer and the Guelph permeameter methods are deemed appropriate for LID bioretention media testing as these instruments have to be inserted into the soil by a depth of at least 15-20 cm which results in measuring the hydraulic conductivity of soil horizons lower than the surface layer. Gupta et al. (1993) studied a number of field measurement methods for determining the saturated hydraulic conductivity. These methods include the Double ring

Infiltrometer, Guelph Permeameter, Rainfall Simulator (RS) and a Guelph infiltrometer (GI). The research concluded that the GP and DRI provide more accurate results for Ksat as the equipment has to be inserted atleast 15-20 cm into the soil representing the subsurface layer. On the other hand, the RS and GI are inserted at depths of 1-5 cm which merely represents the surface layer of soil where the Ksat values are 2.5-3 times higher. For the purpose of these certification protocols, the Guelph Permeameter method was used to measure the saturated hydraulic conductivity, Ksat of the bioretention soil mix for the seven public lands sites that are provided and discussed in Appendix B: Piloting of Certification Protocols.

R. L. Gupta, R. P. Rudra, W. T. Dickinson, N. K. Patni, G. J. Wall (1993). “Comparison of Saturated Hydraulic Conductivity Measured by Various Field Methods”. *Trans ASAE*, 36(1), 51-55.

SoilMoisture Equipment Corporation. (2012). Guelph Permeameter 2800 Operating Instructions.

Farzana Ahmed. (2011) Stormwater U Education Program: Bioretention Systems: The “Dirt” on Soils, Water, and Infiltration - A short procedure of Modified Philip Dunne Infiltrometer

IV Synthetic Runoff Testing

Inspection Procedure	Synthetic Runoff Testing
Timeframe	12-48 hours
Cost	moderate
Level of Experience/Training	moderate to high
Metrics	Measured water levels
Target Objective	Drawdown from the surface within 24hrs subsurface drawdown within 48 hrs.

For a detailed procedure on how to perform a simulated runoff test, please refer to the Green City, Clean Waters Comprehensive Monitoring Plan authored by the Philadelphia Water Department. Appendix D provides a standard operating procedure for simulated runoff testing of green stormwater infrastructure practices.

http://phillywatersheds.org/ltcpu/GCCW%20Comprehensive%20Monitoring%20Plan%20Appendices.pdf

Level 3: Continuous Water Level Monitoring

I. Continuous Water Level Monitoring

Inspection Procedure	Continuous Water Level Monitoring
Timeframe	monthly to bimonthly data downloads for 1-2 years
Cost	moderate
Level of Experience/Training	moderate to high
Metrics	measured water levels
Outcomes	Surface Drawdown Time: within 24hrs Subsurface Drawdown Time: within 72 hrs.

This section is intended to inform the reader about methods of continuous water level monitoring. For more comprehensive guidance, refer to CVC's *LID Monitoring Guidebook*. For more information on the monitoring program at one of our established LID sites refer to the *Elm Drive Technical Monitoring Report.*

Continuous water level monitoring can be performed in rain gardens and bioretention cells fairly easily for a moderate cost. For example, CVC sites are being monitoring using deep and shallow monitoring wells. The deep wells track water levels below the surface and the shallow wells track water levels at the surface. Within these wells, CVC uses piezometers and pressure transducers to monitor depth of water within the bioretention practice. The information collected by this equipment will be used to determine infiltration rates and whether surface ponding is taking place and if it meets its designed drawdown time limit. Infiltration rates can also be tracked overtime, so long-term performance can be assessed.

Selection of Area and Installation

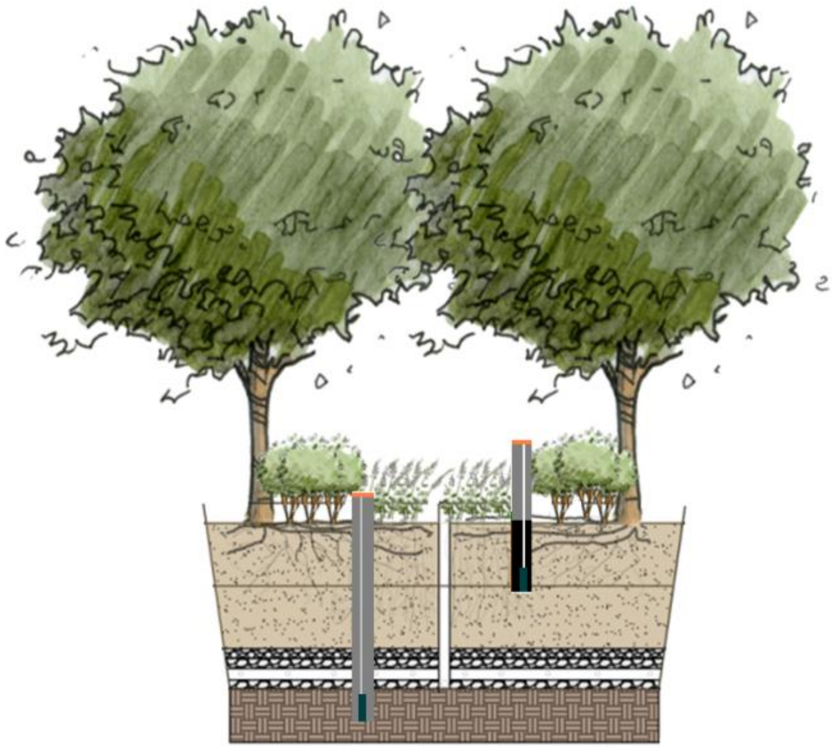
The area you choose to place your monitoring equipment should be the lowest area in the garden as that is where the most water will likely pond and where the soils will become most saturated (i.e. near the overflow structure or outlet location). Only one logger is required to measure infiltration rates, but a second logger will be needed if ponding depths want to be examined.

It is recommended that two loggers are used as that will give the most accurate data. A shallow and deep well are required to monitor the infiltration and surface ponding rates, which can be easily installed. The deep well, which is the one that measures infiltration rates, is either installed during the construction phase of the rain garden, or after construction is complete. It is easier to install your well during construction if possible as it is less intrusive and can be placed deeper. A standard piezometer pipe is used, with a metal well casing on the outside to prevent theft and vandalism. The piezometer pipe is buried so that the well is less visible and obtrusive. The well casing should be level with the ground surface. This will allow more accurate manual measurements to be taken to both calibrate the loggers and confirm their accuracy.

The shallow well will be installed after construction is complete and consists of a pipe is that not perforated below the surface, but is perforated above the surface. This will allow for the ponding water to enter the well and hold water to get an actuate measurement of water above the ground surface. This pipe can then be covered with a larger corrugated pipe for security purposes with a slip cap cover to allow access. It may not be possible to have the shallow well installed during winter periods since these loggers are not intended to freeze, and the shallow wells are susceptible to this. It may be worth installing a trail camera during winter periods, when the shallow loggers need to be removed.

Depending on the type of equipment selected, in addition to the water level loggers, a barometric pressure logger may also be required to compensate the data to get accurate measurements. If you have multiple sites, one barometric pressure logger can be used as long as they are within a few kilometres of each other. Check with your equipment manufacturer/supplier to determine your requirements.

The photo on the left shows a CVC staff member digging to install the deep well. The photo on the right shows the deep well after installation and before it was cut with the casing in place



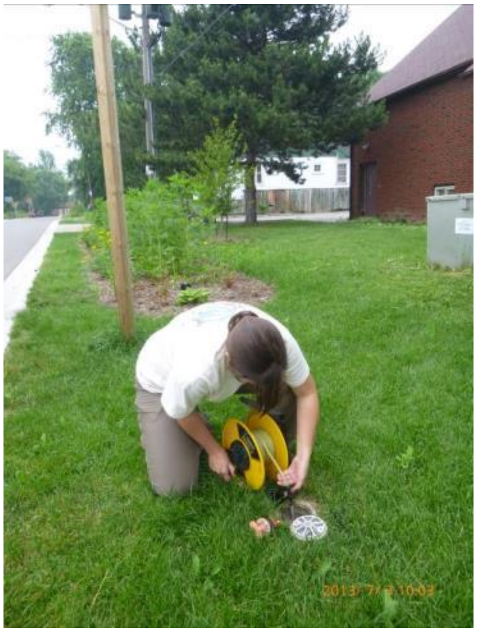
This diagram shows a deep well located on the left, and a shallow well located on the right with loggers resting on the bottom.

Site visits and downloads

It is recommended that the project site is visited biweekly or monthly where the data is downloaded from the loggers and photos of the site are taken but it will depend on the project needs. In the winter the sites are visited monthly as there is less activity taking place and processing the data is a bit easier as there are usually fewer events to analyse. In order to download the loggers in the field you will need a laptop with the appropriate software installed, as well as the proper connection cables. It is a fairly quick process and can be done year-round. A water level tape is also required as manual water level measurements are needed to calibrate the loggers. It is also helpful to have a reference point to ensure the loggers are taking accurate level measurements.

Tasks that occur during a field visit may include:

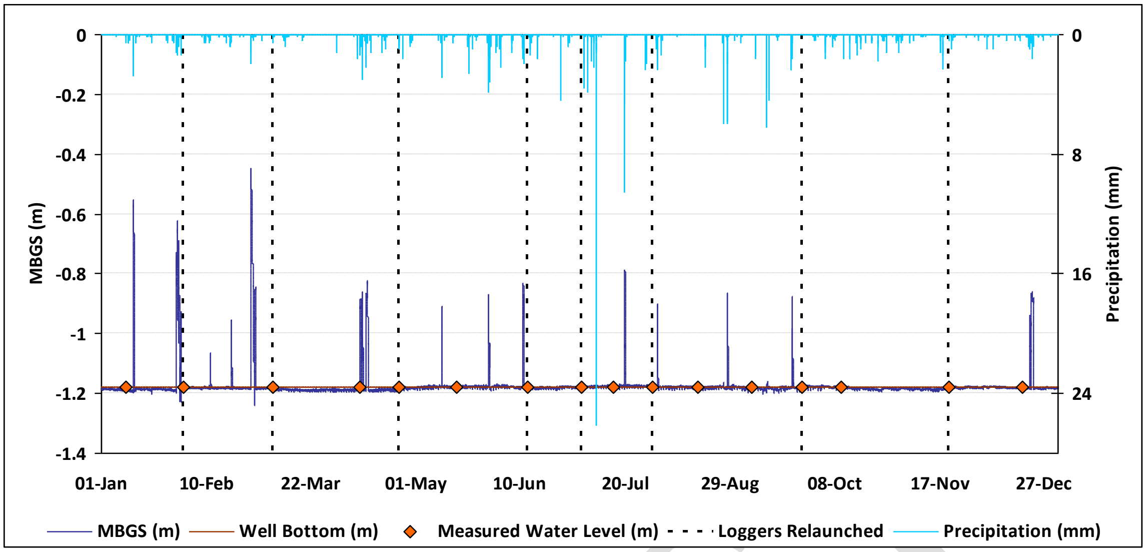
- Taking photos and documenting any changes that might have occurred since the last visit
- Opening the well and taking a water level measurement
- Removing the logger from the well to download the data
- Replacing the logger in the well and securing the well casing
- Taking detailed notes of measurements, downloads, logger information, and site information



The photo on the left shows a CVC staff member taking a manual water level measurement with a level tape. The photo on the right shows CVC staff downloading the loggers at one of the LID sites.

Data compilation and analysis

Once field downloads are complete you can then compensate the data and compile it into a spreadsheet for easy quality control and analysis. The data may need to be compensated with the barometric data collected (again depending on the type of equipment used and the requirements), as well as the manual water level measurements taken. Once the data is processed it can be graphed and if any manual adjustments are needed they can be made. Plotting different practices present in the rain garden, such as the well bottom, ground surface, overflow height, and different media layers (if present) are helpful during analysis. A rain gauge located close by, ideally within 1km, will be needed to analyse different storm events with infiltration rates. The precipitation data can be plotted on the same graph as water level to compare relationships between storm size and duration to infiltration rates. Having the equipment take measurements every ten minutes seems to give a good resolution for moderate analysis. For more in depth analyses you may want to increase the frequency of measurements to every five minutes. The best way to evaluate your data set and identify issues is to graph it, so it is recommended to plot your data frequently.



This graph shows subsurface water level monitoring from a school rain garden.

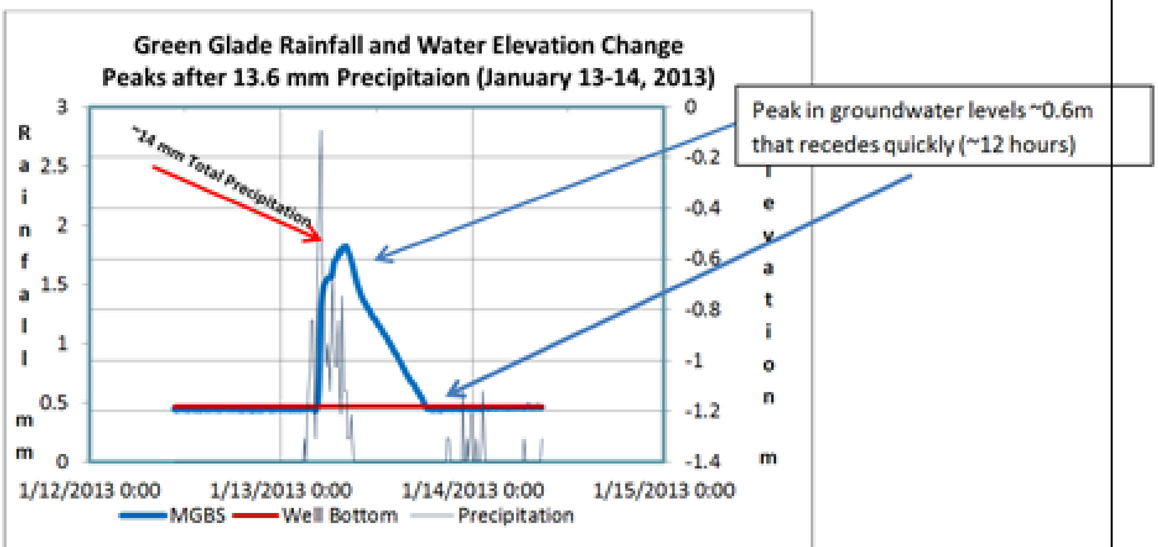
Example Approach for Analysing Data

Relatively Simple Approach

1. Observe infiltration characteristics over seasons and storm events;
2. Observe seasonal variations and critical winter infiltration characteristics (does it infiltrate all winter or freeze-up?)
3. Track infiltration performance over time to detect increases or decreases in performance

More Detailed Approach

1. Estimate the volume of treated runoff and compare to theoretical drainage basin runoff volume for percent treatment.
2. Estimate seasonal changes



Determine Site Draw-down Time.

1. Determine site surface ponding draw-down time based on site hydraulic conductivity, surface area, infiltration rate.
2. Plot continuous water elevation and rainfall data and assess via spreadsheet.
   a. Relatively Simple Approach
      - Determine the number of infiltration/filtration events
        - Smaller storms, many could have longer duration
        - Large more intense storms (usually of shorter duration)
      - Evaluate infiltration rate changes over time by simple shape (height, width and length of water level responses to rainfall).
      - Determine the height of infiltration/filtration events (change from base flow to peak water level.
   b. More detailed assessments
      - Determine the typical rainfall-water level response triggers (6 hour rainfall >8 mm etc.)
      - Estimate site infiltration based on water level recession post storm
      - Calculate theoretical drainage area runoff to bioretention device per event.
      - Plot the theoretical drainage area runoff to site infiltration based on calculations.

Level 4: High-Intensity Monitoring

I. High-Intensity Monitoring

Inspection Procedure	High-Intensity Monitoring
Timeframe	Monthly data collection (more if collecting water quality samples) 1 to 3 years
Cost	High
Level of Experience/Training	High
Metrics	Flow Water Quality
Targeted Objectives	Based on design specifications

This section is intended to inform the reader about methods used in High-Intensity monitoring. For more comprehensive guidance, refer to CVC's *LID Monitoring Guidebook*. For more information on the monitoring program at one of our established LID sites refer to the *Elm Drive Technical Monitoring Report.*

High-Intensity monitoring is the most comprehensive and expensive assessment technique but it can be used to effectively document water volume reduction and peak flow reduction for most stormwater treatment practices by measuring discharge during natural runoff events.

Besides having considerable additional costs, high-intensity monitoring has more potential for missed or erroneous data as compared to other testing protocols such as synthetic runoff tests for the following reasons:

1. Weather is unpredictable and can produce various runoff volumes of various durations with varying pollutant concentrations at various times.
2. In order for a storm event to be monitored correctly and accurately, all the monitoring equipment must be operating correctly and the parameters (water depth, etc.) must be within the quality control limit ranges for the equipment.
3. Equipment malfunction due to rodents, electrical interferences, routine wear, storm damage/loss, or vandalism are common.
4. State-of-the-art continuous monitoring of stormwater runoff is the most expensive of monitoring techniques as it requires trained technicians, proper installation, frequent inspection, runoff flow-gauging, maintenance and adherence to quality control protocols.

Continuous monitoring can provide accurate mass-balance (incoming-outgoing) summaries that have been used to accurately assess (NRC/NSF 2008):

1. individual BMP performance (volume and pollutant reductions) over seasons and annually, particularly for new and innovative techniques;
2. drainage area runoff quality over seasons for comparison to water quality criteria or goals
3. Treatment train performance seasonally and annually.

Selection of Area and Installation

Finding the best water flow monitoring location(s) is the first and most important step in establishing a continuous monitoring site as flow variation will largely determine loading and related uncertainties. Flows must be laminar and not subject to back-watering. Ideally, a pipe weir or pre-manufactured flume weir can be installed for tracking pre-determined height/flow relationships. If not, then pipe flow equations or gauging will have to be accomplished. Existing site plans should be reviewed following a site walk to gain an understanding of the existing drainage system for the study area. For example, CVC uses flow loggers and autosamplers to conduct high-intensity monitoring.

Monitoring station. An external and internal view of the manhole of the monitoring location at Elm Drive.

When sampling for water quality at LID sites and control sites (‘business as usual’ stormwater management) it is important to capture the first flush (the beginning of outflow) and peak flow. Autosamplers are recommended in order to capture the first flush and the peak flow. Autosamplers should be programmed to begin sampling at the beginning of flow and should last for the entire flow event. In cases where sampling with an autosampler is not feasible, grab samples of the outflow can be collected directly. When sampling this way it is important to time the sampling appropriately to get a representative sample of the outflow.

CVC staff member downloading flow data from the logger, along with the autosampler. Autosamplers provide the convenience and ease of sample collection.

The methodology that you use to monitor water quantity will be dependent on the site characteristics and the infrastructure that you are able to install. The data that can be collected include:

- Inflow (how much water is entering your practice)
- Outflow (how much water is exiting your practice)
- Surface ponding (how much water and how long the water ponds on the surface of your practice)
- Water retention (how much water is stored within your practice)

When measuring outflow from your site you will need a rating curve to calculate flow using level data. To generate a rating curve, discharge will need to be manually measured at different stages of flow (low flow, medium flow, high flow).

LID practices are designed to minimize the quantity of water leaving the site through stormwater management infrastructure. Due to this, it is important to gather water quantity data prior to attempting to collect water quality samples. In some cases the practice will retain nearly all stormwater from the contributing drainage area. In cases like this it may not be feasible to collect water quality samples.

Site visits and downloads

Bioretention practices can be monitored year-round to examine both summer and winter performance. Monthly data collection (more if collecting water quality samples) 1 to 3 years. Maintenance to the monitoring equipment and the downloading of collected data occurs weekly to ensure proper site function and regular data compilation and analysis.

At control sites, collect a grab sample for the first flush and a composite sample for the rest of the flow event, LID sites may only need a composite sample over the entire flow event. Collect samples as soon as possible after the sampling program has ended in order to preserve your samples, as some parameters are greatly impacted by temperature and hold times.

Data compilation and analysis

Continuous data allows for a wide range of information to be collected. To assess runoff volume and pollutant load reduction, peak flow reduction, or both by monitoring a stormwater treatment practice, the inflow(s) and outflow(s) must be measured or estimated as in conducting a water budget. The summation of the inflows can then be compared to the summation of the outflows to determine the runoff volume reduction, peak flow reduction, or both. typical urban runoff events are flashy (rapid response) and require continuous flow measurement (or estimation).Pollutant loading changes will require state-of-the-art automated sampling devices to obtain flow-pace or time-weighted sampling that coupled with continuous flows allow estimation of loads.

Regardless of whether sampling a control site or an LID site, composite samples should be flow weighted. When there is higher flow, more water will be allocated to the composite sample. Flow weighted composite samples will give a more accurate depiction of the quality of the water flowing from the site over the entire event.

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Appendix A

Lists of Acronyms and Abbreviations

ASTM	American Society for Testing and Materials
BMP	Best Management Practice(s)
CDA	Contributing Drainage Area
CEC	Cation Exchange Capacity
CVC	Credit Valley Conservation
DRI	Double Ring Infiltrometer
ELC	Ecological Land Classification
EMAN	Environmental Monitoring Assessment Network
GI	Guelph Infiltrometer
GP	Guelph Permeameter
LID	Low Impact Development
MBGS	Meters below ground surface
MOE	Ministry of the Environment
RS	Rainfall Simulator
SWM	Stormwater Management
TDS	Total Dissolved Solids
TKN	Total Kjehldahl Nitrogen
TP	Total Phosphorus
TSS	Total Suspended Solids
WQV	Water Quality Volume

Appendix B – Application of Certification Protocols

Application of Certification Protocols to Elm Drive

Elm Drive Permeable Pavement Lay-bys, sidewalk and bioretention cells

The Elm Drive low impact development (LID) road retrofit is located on Elm Drive West, just south of the Square One Shopping Centre in Mississauga, Ontario. Green infrastructure implemented includes both permeable paver lay-bys within the road right of way (on City of Mississauga property) and bioretention planters on the adjoining property owned by the Peel District School Board (PDSB). Runoff flows from Elm Drive West onto the permeable paver lay-by and into to the bioretention planters via an open pipe. The bioretention cells have a sub-drain also known as a perforated pipe which collects the infiltrated water which than flows to the existing storm sewer. The bioretention soil mix is loamy sand whereas the native soils are clay/weathered shale. Native ornamental herbaceous plants are planted in the bioretention cells topped with mulch.

The draft certification protocols were piloted at seven bioretention sites in the Credit River Watershed over 2012 and 2013. Certification level 3 and the associated protocols were applied in an effort to compare the as-constructed to the original design. All seven protocol methods were applied to Elm Drive. Synthetic runoff testing was not applied as there was not a convenient water source nearby to conduct the test. The protocols applied and pass/fail performance for each is summarized in **Table 1**.

Table 1. Summary of Assumption Protocols for Elm Drive		
Testing Protocol	**Timeframe Test Performed**	**Pass/Fail**
Checklist Inspection	conducted biweekly from July 2012 to Oct 2013	Pass
Vegetation Surveys	Final vegetation survey was completed in September 2013	Pass
Soil Testing	July 2012	Pass
As-Constructed Survey	June 2012	Pass
Infiltration Testing or Synthetic Runoff	Performed October 17th, 2013	Pass
Water Level Monitoring	Data collected from Oct 2012 to Oct 2013.	Pass
Water Flow & Quality Monitoring	Data collected continuously for 2012 and 2013. Flow weighted automatic sampling taken for events in 2012 and 2013.	Pass based on 2013 results

As summarized in Table 1, Elm Drive ***passes*** all testing protocols including the visual inspection, vegetation survey, soil testing, elevation survey, infiltration testing, water level monitoring and Water flow and quality monitoring. The summary report hereon outlines the test or survey findings for each protocol and provides recommendations that need to be implemented to ensure that the LID practice passes all assumption protocols and is constructed to design.

Piloting these certification protocols provide a guidance tool and a standard procedure that business/property owners and municipalities can employ before taking ownership of an LID practice. A thorough certification protocol reduces the risk to the owner that they are assuming a facility that is functioning properly and will not require costly near or long term repairs. These certification protocols are particularly important for stormwater management facilities. A 2007 survey of southern Ontario municipalities found that certification and monitoring protocols for stormwater ponds to be weak or non-existent[i]. This has resulted in many instances of ponds that have been assumed by the municipality that do not meet design requirements. A study of 98 ponds in the Lake Simcoe Conservation Area found that nearly half the ponds failed to meet their design level of service.[ii] Both studies recommended more rigorous certification protocols before assumption, including at a minimum an as-constructed survey. More detailed results on each of the protocols are provided in **Tables 2 - 8**.

Table 2. Testing Protocol: Visual Inspection LEVEL 1			
Assessment Item	**Metric / Passing Threshold**	**Result**	**Pass / Fail**
1. Drainage Area	Contributing drainage area matches the design plans	drainage areas appear to drain to bioretention inlets	Pass
	Drainage area is stabilized and well maintained	all areas are stabilized, no open soil areas or stockpiles	Pass
2. Inlets	Inlets are not obstructed	catch basins have been cleaned, some debris build up where inlet pipe enters planters	Pass
	no erosion at inlets	minor erosion at inlet	Pass
	pre-treatment is in place and functioning	river rock is in place and dissipating flows	Pass
	structurally sound	structurally sound	Pass
	no safety concerns	no safety concerns	Pass
4. Bioretention Bed	surface area matches design (135 sq. m)	measurements show the bed area matches the design	Pass
	no slide slope erosion	minor side slope erosion, related to foot traffic	Pass
	bed is properly graded, no excessive settlement	grades were corrected in July 2011	Pass
	no bed erosion	no bed erosion found	Pass
	no sediment caking or build-up on the surface	no sediment build-up	Pass
	presence of debris and trash (less than 5% coverage)	10% coverage of trash and debris	Fail
	soil is a loamy sand consistency	soil is sand to loamy sand	Pass
	no standing water	no standing water observed	Pass
	mulch depth is 50-100 mm	average depth is 75 mm	Pass
5. Underdrain	underdrain is at the correct	Underdrain appears to be at	Pass

	height (600 mm from top of overflow structure)	correct height, entering overflow structure 600 mm from top.	
6. Vegetation	vegetation cover is > 75 %	80 % coverage	Pass
	vegetation is in good health and established	Vegetation is in good health but has been partially replaced each growing season	Fail
7. Overflow	in place and at the correct elevation (inverts are 200 mm above the bioretention surface)	overflows are in place and invert is at 200 mm from soil surface	Pass
	free of debris and clogging	no clogging or debris	Pass

Comments: The most recent visual inspection was made on Aug 16, 2013. The design of the practice, depressed uncovered planter boxes, results in excessive trash build up. Biweekly or monthly removal of trash will be necessary to maintain a high aesthetic. Overall, the site ***passes*** the visual inspection.

Recommendation: Additional maintenance inputs will be needed to keep the practice clear of trash and ensure the vegetation establishes.

Table 3. Testing Protocol: Landscaping Survey

Assessment Item	**Metric / Passing Threshold**	**Result**	**Pass / Fail**
1. What percentage of the ground is covered?	80%	95%	Pass
2. What percentage of plants is invasive/ undesirable?	5%	0%	Pass
3. What percentage of planted species has died?	5%	4%	Pass
4. What percentage of the species is thriving? Ex. ranked 3 or higher	80%	100%	Pass
5. Does the site meet aesthetic goals? Ex. colour, year round interest, clean formal appearance and planter visibility	Yes	Yes	Pass

Comments: Landscaping assessments were conducted in September 2013 and the site ***passes*** the landscaping survey protocol.

Recommendation: Shift to post establishment maintenance program.

Table 4. Testing Protocol: Soil Testing LEVEL 2			
Assessment Item	**Metric / Passing Threshold**	**Result**	**Pass / Fail**
1. Texture: Sand 2.0 – 0.075 mm dia.: Silt and Clay < 0.05mm dia., sieve 270	86 - 92 % by weight 8- 12 % by weight	89% by weight 11% by weight	Pass
2. Organic content:	3- 5% by dry weight	0.7 % by weight	Fail
3. Cationic exchange capacity (CEC):	>10 meq/100 g	10 meq/100 g	Pass
4. Soil Acidity:	5.5 - 7.5 pH	7.5 pH	Pass
Comments: Overall, the site ***passes*** the soil testing protocol. To compensate for the low organic content, leaf matter and grass clippings were mixed into the top layer of soil and 75 mm of shredded hardwood mulch were added to the surface. **Recommendation: The addition of compost matter is only recommended if vegetation is unable to survive but if the vegetation seems in optimal health, the low organic content is sufficient for vegetation to survive and no alterations are needed.**			

Table 5. Testing Protocol: As-Constructed Survey (planter 3) LEVEL 2			
Assessment Item	**Metric / Passing Threshold**	**Result**	**Pass / Fail**
1. Contributing drainage area:	900 sq. m	1,228 sq. m	Pass
2. Bioretention area	22.5 sq. m	19 sq. m	Pass
3. Surface storage volume	20 cu m	26 sq. m	Pass
4. Subsurface Storage Volume above the underdrain invert	20 cu m	33 cu m	Pass
5. Subsurface storage below the underdrain invert	12 cu m	19 cu m	Pass
6. Inlet grades:	inlets are in the correct location as per design plans and allow positive drainage from the catchment area	The catch basin inlet elevations are lower as compared to the contributing drainage area elevations ensuring positive drainage into the system	Pass
Comments and Corrective Actions Taken:			

- The as-built drainage area is almost half of the designed plan. The site still functions properly because a smaller as-built drainage area means the facility is oversized in reality.
- The as-built bioretention area is only 5 sq. m smaller than the designed plan which is acceptable.
- The total storage capacity for the site in increased by an additional 62 cu m as-constructed.

Overall, the Elm Drive site ***passes*** the as-constructed survey because the contributing drainage area has been reduced which increases the total storage capacity (i.e.: oversized).

Recommendation: The underdrain of the facility should sit at the bottom of the LID facility to ensure there is no dead storage. Given that the Elm Drive site has clay type native soils with very low infiltration rates, having dead storage below the underdrain has a reduced exfiltration rate into the surrounding native soils. Future LID systems should be designed for no dead storage below the underdrain.

Table 6. Testing Protocol: Infiltration Testing LEVEL 2

Assessment Item	**Metric / Passing Threshold**	**Result**	**Pass / Fail**
1. Infiltration Rate	> 25 mm/hr	Ranges from 125 mm/hr to 140 mm/hr with an average infiltration rate of 133 mm/hr	Pass

Comments: The Guelph Permeameter test was performed on October 17th, 2013 at two locations within planter 6 (most downstream planter) and planter 4 (middle planter) for a total of 4 infiltration tests at the site. Overall, the facility ***surpasses*** the infiltration testing protocol as the in-situ infiltration rates are higher than the minimum threshold of 25 mm/hr. The results provided above are the in-situ saturated hydraulic conductivity measurements which equal the infiltration rate. The sorptivity is influenced by the initial and final moisture contents. As the moisture content approaches saturation, sorptivity tends to zero and the infiltration rate equals to the field saturated hydraulic conductivity[iii].

Recommendation: Soil composition and infiltration tests confirmed that the bioretention soil mix is performing at the proper infiltration rate. At this time, no soil alterations are recommended.

Table 7. Testing Protocol: Continuous Water Level Monitoring LEVEL 3			
Assessment Item	**Metric / Passing Threshold**	**Result**	**Pass / Fail**
1 – Surface Drawdown Time (hrs)	24 hrs	No surface ponding observed	Pass
2. Subsurface Drawdown Time (hrs)	48 hrs	Ranges from 28 hrs to 59 hrs with an average 41 hrs.	Pass
Comments: The as-constructed bioretention facility ***passes*** the water level monitoring test as the average subsurface drawdown time is less than 48 hours. The water level analysis was performed on rain events greater than 10 mm and the assessment of surface ponding drawdown rates and times was neglected due to inadequate data. Only above and below drain drawdown rates and times were calculated based on this data. As a lesson learned, additional information is needed to perform a complete analysis including surface ponding capacity and duration. **Recommendation: No recommendations at this time.**			

Table 8. Testing Protocol: Outlet Flow and Water Quality Monitoring LEVEL 4			
Assessment Item	**Metric / Passing Threshold**	**Result**	**Pass / Fail**
1. Water Quality	80% removal of total suspended solids (TSS)	92.2% removal of TSS	Pass
2. Erosion Control	retention of 5 mm	15-20 mm retained	Pass
3. Water Balance	Minimum of 3 mm of infiltration	5-11 mm infiltration	Pass
Comments: The observed performance far exceeds the design criteria for the project and the 2012 CVC New Development Criteria for Stormwater Management. The site ***passes*** the outlet flow and water quality monitoring protocol. For full explanation of the monitoring methodology and analysis see the Elm Drive Low Impact Development Monitoring Preliminary Technical Site Report: Years 1 and 2, Chapter 6 on Results and Interpretation. **Recommendation: Site is performing beyond protocol requirements and no alterations are necessary at this time.**			

Discussion

All testing protocols were completed by November 2013. The Elm Drive site ***passes*** all testing protocols as summarized above. However, for each individual protocol, several issues have been identified which need to be addressed for optimal performance. These issues include:

- *Visual Inspection* – There is extreme trash and debris build up due to the depressed and uncovered design of the planters. The maintenance plan needs to include at least biweekly clean out episodes.
- *Landscaping Survey - Rudbeckia hirta* need to be replaced with a different plant species. There was a high plant die off in the first year. The landscape plan was enhanced with trees and shrubs and regular maintenance was enforced.
- *Soil Testing* – Low organic content in soils. Rather than replace the soil, mulch was worked into the top layer of soil and added to the surface layer.
- *As-built Survey* - The elevation grade of the bioretention soil was too high and needed to be regraded to increase surface ponding capacity.

- *Other* - fall hazards were also identified with the deep planters, and a railing was added around the planters.

The visual inspection was able to address many issues above ground; however, the other protocols reveal issues occurring below the surface that are not caught with a visual inspection. The low organic content would not have been identified without soil testing. The water level monitoring also indicated that the bottom 150-200 mm of the practice does not fully drain given the dead storage capacity and the low exfiltration into native subsoils. However, the comprehensive flow monitoring showed that the system is still exceeding the design requirements.

Application of Certification Protocols to Green Glades Public School

Green Glade Sr. Public School is a senior elementary school located in south Mississauga, adjacent to Rattray Marsh, a provincially significant wetland. In 2011, Green Glade and Peel District School Board (PDSB) staff worked with Credit Valley Conservation (CVC) to retrofit the school property to incorporate a rain garden low impact development (LID) practice. The rain garden accepts runoff from a portion of the school's roof as well as runoff from a section of the parking lot. The rain garden accepts concentrated runoff from the roof and parking lot via a roof leader and curb inlets. The bioretention soil mix is composed of clayey sand where the native soils were sandy soils. The plant community is native meadow topped with mulch to protect vegetation.

Green Glades Senior Public School Rain Garden

The draft certification protocols were piloted at seven bioretention sites in the Credit River Watershed over 2012 and 2013. Certification level 3 and the associated protocols were applied at Green Glades Bioretention Area in an effort to compare the as-constructed to the original design. Of the seven protocol methods, six were applied to Green Glades. Synthetic runoff testing was not applied as there was not a convenient water source nearby to conduct the test. Also, outlet flow and water quality monitoring has not been applied due to budget constraints. The protocols applied and pass/fail performance for each is summarized in **Table 1**.

Table 1. Summary of Certification Protocols for Green Glades

Testing Protocol	Timeframe Test Performed	Pass/Fail
Checklist Inspection	Conducted October 29th, 2013	Pass
Vegetation Surveys	Final vegetation survey completed in September 2013	Pass
Soil Testing	July 2012	Pass
As-Constructed Survey	June 2012	Pass
Infiltration Testing or Synthetic Runoff	Test performed on October 29th, 2013	Pass
Water Level Monitoring	Data collected from Oct 2012 to Oct 2013	Pass
Water Flow & Quality Monitoring	Not applied	-

Green Glade's Rain Garden ***passes*** the visual inspection, infiltration testing, and water level monitoring. However, the site currently fails the vegetation survey, soil test and elevation survey protocols in comparison to the original design specifications and details. The summary report hereon outlines the test or survey findings for each protocol and provides recommendations that need to be implemented to ensure that the LID practice passes all assumption protocols and is constructed to design.

Piloting these certification protocols provide a guidance tool and a standard procedure that business/property owners and municipalities can employ before taking ownership of an LID practice. A thorough certification protocol reduces the risk to the owner that they are assuming a facility that is functioning properly and will not require costly near or long term repairs. These certification protocols are particularly important for stormwater management facilities. A 2007 survey of southern Ontario municipalities found that certification and monitoring protocols for stormwater ponds to be weak or non-existent[iv]. This has resulted in many instances of ponds that have been assumed by the municipality that do not meet design requirements. A study of 98 ponds in the Lake Simcoe Conservation Area found that nearly half the ponds failed to meet their design level of service.[v] Both studies recommended more rigorous certification protocols before assumption, including at a minimum an as-constructed survey. More detailed results on each of the protocols are provided in **Tables 2 - 7**.

Table 2. Testing Protocol: Visual Inspection LEVEL 1

Assessment Item	Metric / Passing Threshold	Result	Pass / Fail
1. Drainage Area	Contributing drainage area matches the design plans	Parking lot grading towards the bioretention seems to slope away. The garden is currently sloped as such to meet future upgrades to the parking lot.	Pass
	Drainage area is stabilized and well maintained	Yes	Pass
2. Inlets	Inlets are not obstructed	some debris build up where inlet pipe enters planters	Pass
	no erosion at inlets	None	Pass
	pre-treatment is in place and functioning	river rock is in place and dissipating flows	Pass
	structurally sound	Yes	Pass
	no safety concerns	None	Pass
4. Bioretention Bed	surface area matches design (135 sq m)		
	no slide slope erosion	No slide slope erosion	Pass
	bed is properly graded, no excessive settlement		
	no bed erosion	No bed erosion	Pass
	no sediment caking or build-up on the surface	No sediment building up or caking	Pass
	presence of debris and trash (less than 5% coverage)	Minimal garbage present (<5%)	Pass
	soil is a loamy sand consistency	Yes	Pass
	no standing water	None	Pass

	mulch depth is 50-100 mm	<30mm mulch depth	Fail
5. Underdrain	underdrain is at the correct height (600 mm from top of overflow structure)	-	-
6. Vegetation	vegetation cover is > 75 %	Rain garden well covered by vegetation	Pass
	vegetation is in good health and established	Plants are in good health	Pass
7. Overflow	in place and at the correct elevation	-	-
	free of debris and clogging	Clogged with leave debris	Fail

Comments: The most recent visual inspection was made on October 29th, 2013. Overall the practice ***passes*** the visual inspection. However, additional changes need to be made to ensure the practice is working properly such as adding a layer of mulch to ensure atleast 50 mm is present.

Recommendation: Additional survey investigation is required because the drainage area plays a key role in sizing the LID system. Visual inspection indicates that there is no positive grade towards the bioretention area.

Table 3. Testing Protocol: Landscaping Survey

Assessment Item	Metric / Passing Threshold	Result	Pass / Fail
1. What percentage of the ground is covered?	80%	90%	Pass
2. What percentage of plants is invasive/ undesirable?	5%	2%	Pass
3. What percentage of planted species has died?	5%	0%	Pass
4. What percentage of the species is thriving? Ex. ranked 3 or higher	80%	85%	Pass
5. Does the site meet aesthetic goals? Ex. colour, year round interest, clean formal appearance and planter visibility	Yes	Yes	Pass

Comments: Landscaping assessments were conducted in September 2013. Some of the vegetation has only had one growing season to establish. Sparse planting hinders aesthetic of site and more colours should be added to the garden. Overall, the rain garden looks good but surrounding area needs to be vegetated.

Recommendation: There are no recommendations at this time.

Table 4. Testing Protocol: Soil Testing LEVEL 2

Assessment Item	Metric / Passing Threshold	Result	Pass / Fail
1. Texture: Sand 2.0 – 0.075 mm dia.: Silt and Clay < 0.05mm dia., sieve 270	 86 - 92 % by weight 8- 12 % by weight	 87 % by weight 13% by weight	Pass
2. Organic content:	3- 5% by dry weight	1.9% by weight	Fail

3. Cationic exchange capacity (CEC):	>10 meq/100 g	19.5 meq/100 g	Pass
4. Soil Acidity:	5.5 - 7.5 pH	7.1 pH	Pass

Comments: Overall the facility passes the soil testing protocol as it does not meet the required objectives for texture and organic content.

Recommendation: Further investigation needs to be done to determine the mixing strategy that was used for the bioretention soil media. A failed soil test could trigger replacement if under warranty or further observation and testing through water level monitoring. In order to compensate for the low organic matter, shredded hardwood mulch can also be added to the surface which releases organic content over time. However, some studies have found that the addition of organic matter results in nutrient export (phosphorus and nitrate) into the effluent quality. The addition of organic matter is only recommended if vegetation is unable to survive but if the vegetation seems in optimal health, the low organic content is sufficient for vegetation to survive.

Table 5. Testing Protocol: As-Constructed Survey LEVEL 2

Assessment Item	**Metric / Passing Threshold**	**Result**	**Pass / Fail**
1. Contributing drainage area:	317.9 sq m	42 sq m	Fail
2. Bioretention area	11 sq m	9 sq m	Pass
3. Surface storage volume	-	0.8 cu m	Pass
4. Subsurface Storage Volume above the underdrain invert	-	-	-
5. Subsurface storage below the underdrain invert	-	-	-
6. Total storage capacity (water quality storage volume)	13.2 cu m	11.5 cu m	Pass
7. Inlet grades:	inlets are in the correct location as per design plans and allow positive drainage from the catchment area		

Comments and Corrective Actions Taken:

- The as-built drainage area is relatively smaller than specified in the design plans. The bioretention area is not receiving any appreciable runoff due to the general grading of the parking lot. The eastern and south-western portions are sloped away from the bioretention area and the catch basin configuration causing runoff to bypass the system. Runoff is designed to be directed past the sidewalk through two grates and into the rip-rap on the bioretention area perimeter. The survey data suggests that insufficient grading exists to direct water to either grate, and that the southern grate may be entirely ineffective as an inlet.
- The as-built total storage capacity matches the design plans.

Overall, the Green Glades facility ***passes*** the as-constructed survey protocol because with future upgrades to the parking lot, there will be positive flow into the rain garden.

Recommendation: A pre-construction survey should be performed of the contributing drainage area before the LID facility is installed to ensure positive drainage towards the intended inlets and any adjustments should be accounted for within the LID design plans.

Table 6. Testing Protocol: Infiltration Testing LEVEL 2

Assessment Item	**Metric / Passing Threshold**	**Result**	**Pass / Fail**
1. Infiltration Rate	> 25 mm/hr	Ranges from 79 mm/hr to 101 mm/hr with an average infiltration rate of 90 mm/hr	Pass

Comments: The Guelph Permeameter test was performed on October 23rd and 29th, 2013 in three spots spanning the length of the bioretention facility and the results were averaged as presented above. Overall, the facility ***passes*** the infiltration testing protocol as it is greater than the infiltration capacity threshold of 25 mm/hr. The results provided above are the in-situ saturated hydraulic conductivity measurements which equal the infiltration rate. The sorptivity is influenced by the initial and final moisture contents. As the moisture content approaches saturation, sorptivity tends to zero and the infiltration rate equals to the field saturated hydraulic conductivity[vi].

Recommendation: The Guelph Permeameter is a simple and fast method for performing infiltration tests, however, it is intended for native soils and any inaccuracies for use in bioretention soils are currently unknown. It is recommended to duplicate the infiltration results with other test methods such as the Double Ring Infiltrometer for higher accuracy.

Table 7. Testing Protocol: Continuous Water Level Monitoring LEVEL 3

Assessment Item	**Metric / Passing Threshold**	**Result**	**Pass / Fail**
1 – Surface Drawdown Time (hrs)	24 hrs	-	-
2. Subsurface Drawdown Time (hrs)	48 hrs	Ranges from 0.5 hrs to 2 hr with an average of 1.1 hrs	Pass

Comments: The as-constructed bioretention facility ***passes*** the water level monitoring test as the subsurface drawdown time is less than 48 hours. The rain garden is currently treating a small drainage area and as a result it is over performing. The water level analysis was performed on rain events greater than 10 mm and the assessment of surface ponding drawdown rates and times was neglected due to inadequate data. As a lesson learned, additional information is needed to perform a complete analysis including surface ponding capacity and duration as recommended below.

Recommendation: In addition to the subsurface observational well, a second observational well should be added to the surface to monitor surface ponding and duration to make certain that the as-constructed facility meets the 24 hours design criteria.

Discussion

All testing protocols were completed by November 2013. The Green Glades site ***passes*** all testing protocols given that the following key assessment items are rectified:

- *Visual Inspection* – More mulch needs to be added to maintain the required depth and cover up bare soil spots. The inlet and overflow grates need to be cleared of leave debris to ensure a clear flow path.
- *Landscaping Survey* – Some plants seem to have gone through only one growing season and there are sparse plantings that hinder the overall aesthetic of the site. Given that vegetation plays a key role in LID function, more colours should be added to the garden and the surrounding areas need to be vegetated to maintain the overall aesthetic of the site.
- *Soil Testing* – There is a low organic content which can be compensated for with the addition of organic matter such as shredded mulch which leaches organic materials over time and ensure adequate nutrient supply for plant survival.
- *As-built Survey* - The as-built drainage area is relatively smaller than specified in the design plans. The rain garden was graded to meet future upgrades that are planned for the parking lot when the lot will be raised and have positive flow draining into the garden.

In addition to the visual inspection, other testing protocols assist in evaluating the site better with respect to grading and the need for positive drainage into the bioretention areas. All protocols need to be assessed as a whole to truly determine the function of the LID site.

Application of Certification Protocols to Lakeside Park

Lakeside Park is one of the City of Mississauga's newest parks located on Lakeshore Road West, east of Winston Churchill Blvd in Mississauga, ON. Green infrastructure at Lakeside Park includes a pervious concrete overflow parking area, bioswale, green roof, and a reclaimed water irrigation system that recycles water from the bioswale and splash pad. The bioswale (i.e.: bioretention) is designed as such that it accepts sheet flow runoff generated from the adjacent parking lot that enters the bioswale through a series of curb cuts and discharge to a main sub-drain also known as a perforated pipe. The bioswale media is loamy sand where as the native soils are of mixed clay fill over sand and gravel. The bioswale is planted with native sedge grasses topped with shredded pine mulch.

Lakeside Park bioretention swale takes runoff from the surrounding parking lot.

The draft assumption protocols were piloted at seven bioretention sites in the Credit River Watershed over 2012 and 2013. Certification level 3 and the associated protocols were applied at Lakeside Park Bioretention Area in an effort to compare the as-constructed to the original design. Of the seven protocol methods, six were applied to Lakeside Park. Synthetic runoff testing was not applied as there was not a convenient water source nearby to conduct the test. Also, outlet flow and water quality monitoring has not been applied due to budget constraints. The protocols applied and pass/fail performance for each is summarized in **Table 1**.

Table 1. Summary of Certification Protocols for Lakeside Park

Testing Protocol	Timeframe Test Performed	Pass/Fail
Checklist Inspection	Conducted November 4th, 2013	Pass
Vegetation Surveys	completed in September 2013	Pass
Soil Testing	July 2012	Fail
As-Constructed Survey	June 2012	Fail
Infiltration Testing or Synthetic Runoff	Infiltration Test performed on November 4th, 2013	Pass
Water Level Monitoring	Data collected from Oct 2012 to Oct 2013 and analysis has been completed.	Pass
Water Flow & Quality Monitoring	Not applied	-

Lakeside Park ***passes*** the visual inspection, vegetation survey, infiltration testing, and water level monitoring. However, the site currently fails the soil test and as-constructed survey protocols in comparison to the original design specifications and details. The summary report hereon outlines the test and/or survey findings for each protocol and provides recommendations that need to be implemented to make certain the LID practice passes all certification protocols and is constructed to design before the municipality takes assumption of the practice.

Piloting these certification protocols provide a guidance tool and a standard procedure that business/property owners and municipalities can employ before taking ownership of an LID practice. A thorough certification protocol reduces the risk to the owner that they are assuming a facility that is functioning properly and will not require costly near or long term repairs. These certification protocols are particularly important for stormwater management facilities. A 2007 survey of southern Ontario municipalities found that certification and monitoring protocols for stormwater ponds to be weak or non-existent[vii]. This has resulted in many instances of ponds that have been assumed by the municipality that do not meet design requirements. A study of 98 ponds in the Lake Simcoe Conservation Area found that nearly half the ponds failed to meet their design level of service.[viii] Both studies recommended more rigorous certification protocols before assumption, including at a minimum an as-constructed survey. More detailed results on each of the protocols are provided in **Tables 2 - 7**.

Table 2. Testing Protocol: Visual Inspection LEVEL 1			
Assessment Item	**Metric / Passing Threshold**	**Result**	**Pass / Fail**
1. Drainage Area	Contributing drainage area matches the design plans	The parking lot seems to slope towards the bioretention area and so the contributing drainage area seems accurate in the field.	Pass
	Drainage area is stabilized and well maintained	Yes	Pass
2. Inlets	Inlets are not obstructed	No obstruction by the inlets as the park is well maintained	Pass
	no erosion at inlets	None	Pass
	pre-treatment is in place and functioning	N/A	-
	structurally sound	Yes	Pass
	no safety concerns	None	Pass
4. Bioretention Bed	surface area matches design (165 sq m)	165 sq m per as-built which matches the design plans exactly.	Pass
	no slide slope erosion	Minimal side slope erosion – mainly due to foot traffic	Pass
	bed is properly graded, no excessive settlement	No settlement visible – bioretention seems properly graded	Pass
	no bed erosion	No bed erosion	Pass
	no sediment caking or build-up on the surface	No sediment building up or caking	Pass
	presence of debris and trash (less than 5% coverage)	Minimal garbage present (<5%)	Pass
	soil is a loamy sand consistency	Soil is loamy sand mainly near the downstream end where the catchbasin overflow is located. As we move upstream, clay was	Pass

		found at shallower depths (within 30 cm).	
	no standing water	Saturated soils upstream of facility but no surface ponding present	Pass
	mulch depth is 50-100 mm	Mulch depth > 50 mm	Pass
5. Underdrain	underdrain is at the correct height	Yes	Pass
6. Vegetation	vegetation cover is > 75 %	Rain garden well covered by vegetation	Pass
	vegetation is in good health and established	All plants seem in good health	Pass
7. Overflow	in place and at the correct elevation	-	-
	free of debris and clogging	No debris present at overflow catchbasin therefore, no potential clogging.	Pass
Comments: The most recent visual inspection was made on October 29th, 2013. Overall the practice **PASSES** the visual inspection. **Recommendation: There are no recommendations at this time.**			

Table 3. Testing Protocol: Landscaping Survey			
Assessment Item	**Metric / Passing Threshold**	**Result**	**Pass / Fail**
1. What percentage of the ground is covered?	80%	85%	Pass
2. What percentage of plants is invasive/ undesirable?	5%	2%	Pass
3. What percentage of planted species has died?	5%	3%	Pass
4. What percentage of the species is thriving? Ex. ranked 3 or higher	80%	92%	Pass
5. Does the site meet aesthetic goals? Ex. colour, year round interest, clean formal appearance and planter visibility	Yes	Yes	Pass
Comments: Landscaping assessments were conducted in September 2013. Overall, the site passes the vegetation survey. Some of the vegetation has only had one growing season to establish. Most has had more than 2 seasons. Plants are full and showing good fall colour. **Recommendation: Shift to post establishment maintenance program.**			

Table 4. Testing Protocol: Soil Testing LEVEL 2			
Assessment Item	**Metric / Passing Threshold**	**Result**	**Pass / Fail**
1. Texture: Sand 2.0 – 0.075 mm dia.: Silt and Clay < 0.05mm dia., sieve 270	 86 - 92 % by weight 8- 12 % by weight	 64 % by weight 36 % by weight	Fail
2. Organic content:	3- 5% by dry weight	1.5% by weight	Fail
3. Cationic exchange capacity (CEC):	>10 meq/100 g	13 meq/100 g	Pass
4. Soil Acidity:	5.5 - 7.5 pH	7.1 pH	Pass

Comments: Overall the facility ***fails*** the soil testing protocol as it does not meet the required objectives for texture and organic content. The soil samples for the composite may have come outside of the bioretention area and resulted in higher clay particles. Also, this site was one of the first bioretention practices in the GTA and suppliers had not yet refined a mixing strategy that met the specification.

Recommendation: Further monitoring and observation is recommended as outlined below –

- **Infiltration test to evaluate hydraulic conductivity**
- **Continuous water level monitoring to evaluate the surface and subsurface drawdown rates and properties**

Table 5. Testing Protocol: As-Constructed Survey LEVEL 2			
Assessment Item	**Metric / Passing Threshold**	**Result**	**Pass / Fail**
1. Contributing drainage area:	3,600 m^2	3, 670 m^2	Pass
2. Bioretention area	165 m^2	165 m^2	Pass
3. Surface storage volume	-	1.9 m^3	-
4. Subsurface Storage Volume above the underdrain invert	-	-	-
5. Subsurface storage below the underdrain invert	-	-	-
6. Total storage capacity (water quality storage volume)	115.5 m^3	95.1 m^3	Fail
7. Inlet grades:	inlets are in the correct location as per design plans and allow positive drainage from the catchment area	The runoff is designed to travel as sheet flow and enter the bioretention cell. Based on the as-built survey elevations, the bioretention is receiving positive drainage from the parking lot.	Pass

Comments and Corrective Actions Taken:

- The impervious area draining to the bioswale is the same for the as-constructed survey as in the design plans.

- The total bioretention area as-constructed matches the design plans.
- The as-constructed total storage capacity available is 20 m^3 smaller than the design plan due to the reduced ponding surface. The practice still functions as a bioswale but may only treat a 20 mm event as opposed to the design 25 mm event.

Overall, the bioswale ***passes*** the as-constructed survey protocols. The storage capacity is slightly smaller than the design but the facility still meets the MOE's required minimum sizing for Level 1 Enhanced Protection.

Recommendation: The facility could be upgraded in the future by regrading the surface to increase surface ponding capacity and provide extra storage volume.

Table 6. Testing Protocol: Infiltration Testing LEVEL 2

Assessment Item	Metric / Passing Threshold	Result	Pass / Fail
1. Infiltration Rate	> 25 mm/hr	Ranges from 7 mm/hr to 70 mm/hr with an average infiltration rate of 30 mm/hr	Pass

Comments: The Guelph Permeameter test was performed on November 4th, 2013 in three spots spanning the length of the bioretention facility and the results were averaged as presented above. Overall, the facility ***passes*** the infiltration testing protocol as it is greater than the infiltration capacity threshold of 25 mm/hr. The results provided above are the in-situ saturated hydraulic conductivity measurements which equal the infiltration rate. The sorptivity is influenced by the initial and final moisture contents. As the moisture content approaches saturation, sorptivity tends to zero and the infiltration rate equals to the field saturated hydraulic conductivity[ix].

Recommendation: Despite the failed soil test as discussed in table 4, the bioretention soil mix seems to be infiltrating within the required range of 25 mm/hr. No further soil alterations are recommended and further investigation should be performed with continuous water level monitoring.

Table 7. Testing Protocol: Continuous Water Level Monitoring LEVEL 3

Assessment Item	Metric / Passing Threshold	Result	Pass / Fail
1 – Surface Drawdown Time (hrs)	24 hrs	The bioretention cell was designed with little to no surface ponding depth	N/A
2. Subsurface Drawdown Time (hrs)	48 hrs	Ranges from 2.4 hrs to 8.2 hr with an average of 4.8 hrs	Pass

Comments: The as-constructed bioretention facility ***passes*** the water level monitoring test as the subsurface drawdown time is less than 48 hours. The water level analysis was performed on rain events greater than 10 mm and the assessment of surface ponding drawdown rates and times was neglected due to inadequate data. The average loss rate associated with these drawdown times is 35.10 mm/hr where loss rate represents all outputs including filtration, infiltration and evapotranspiration.

Recommendation: The site is performing as design and so no alterations are required at this time.

Discussion
All testing protocols were completed by November 2013. The Lakeside Park site ***passes*** most testing protocols except for the Soil testing and as-built survey protocols. The key assessment items identified in these individual protocols are discussed below along with the recommendations that should be implemented:

- *Soil Testing* – The soil mixture does not meet the optimum texture composition for Coarse sand and silt/clay particles without having to replace the entire soil matter. There is a low organic content which can be compensated for with the addition of organic matter such as leaf matter or grass clippings into the top layer of the soil to ensure adequate nutrient supply for plant survival.
- *As-built Survey* - The as-constructed total storage capacity available is 20 m^3 smaller than the design plan due to the reduced ponding surface. The practice still functions as a bioswale but may only treat a 20 mm event as opposed to the design 25 mm event. The facility could be upgraded in the future by regrading the surface to increase surface ponding capacity and provide extra storage volume.

It is important to evaluate the results for all testing protocols side by side from a visual inspection to water level monitoring and truly analyze whether the constructed LID facility meets the design requirements.

<u>Application of Certification Protocols to O’ Connor Park</u>

O’Connor Park is located on Bala Drive in the west end of Mississauga, Ontario in the Sawmill Creek sub-watershed. The practices of the park include: two soccer fields, wetland with a habitat island, naturalized areas, playground, walkway adjacent to the wetland and parking lot with innovative LID practices including permeable pavement and a central bioretention cell. Typical rainfall events are managed via the permeable pavement parking spots but larger rainfall events creating sheet flow are directed to the bioretention cell through the curb cut-outs. Runoff that infiltrates into the bioretention cell gets collected into a sub-drain or so called a perforated pipe.

O’ Connor Park Permeable Pavement and Central Bioretention Cell

The draft assumption protocols were piloted at seven bioretention sites in the Credit River Watershed over 2012 and 2013. Certification level 3 and the associated protocols were applied at O’ Connor Park Bioretention Area in an effort to compare the as-constructed to the original design. Of the seven protocol methods, six were applied to O’ Connor Park. Synthetic runoff testing was not applied as there was not a convenient water source nearby to conduct the test. Also, outlet flow and water quality monitoring has not been applied due to budget constraints. The protocols applied and pass/fail performance for each is summarized in **Table 1**.

Table 1. Summary of Certification Protocols for O’ Connor Park

Testing Protocol	**Timeframe Test Performed**	**Pass/Fail**
Checklist Inspection	Conducted November 4th, 2013	Pass
Vegetation Surveys	Final vegetation survey was conducted in September 2013	Pass
Soil Testing	July 2012	Fail
As-Constructed Survey	June 2012	Pass
Infiltration Testing or Synthetic Runoff	Test performed on November 4th, 2013	Fail*
Water Level Monitoring	Data collected from Oct 2012 to Oct 2013	Fail
Water Flow & Quality Monitoring	Not applied	-
*Refer to Table 6 for Details on the Infiltration Testing Protocol		

As summarized in Table 2, O’ Connor Park ***<u>passes</u>*** the visual inspection, vegetation survey, elevation survey, and infiltration testing. However, the site currently fails the soil testing protocol and water level monitoring protocols which need to be addressed to make certain that the LID practice is built to design specifications and drawdown rates. The summary report hereon outlines the test or survey findings for each protocol and provides recommendations that need to be implemented to ensure that the LID practice passes all assumption protocols and is constructed to design.

Piloting these certification protocols provide a guidance tool and a standard procedure that business/property owners and municipalities can employ before taking ownership of an LID practice. A thorough certification protocol reduces the risk to the owner that they are assuming a facility that is functioning properly and will not require costly near or long term repairs. These certification protocols are particularly important for stormwater management facilities. A 2007 survey of southern Ontario municipalities found that certification and monitoring protocols for stormwater ponds to be weak or non-existent[x]. This has resulted in many instances of ponds that have been assumed by the municipality that do not meet design requirements. A study of 98 ponds in the Lake Simcoe Conservation Area found that nearly half the ponds failed to meet their design level of service.[xi] Both studies recommended more rigorous certification protocols before assumption, including at a minimum an as-constructed survey. More detailed results on each of the protocols are provided in **Tables 2 - 7**

Table 2. Testing Protocol: Visual Inspection LEVEL 1			
Assessment Item	**Metric / Passing Threshold**	**Result**	**Pass / Fail**
1. Drainage Area	Contributing drainage area matches the design plans	Positive drainage are entering the permeable pavement and bioretention cell.	Pass
	Drainage area is stabilized and well maintained	Yes	Pass
2. Inlets	Inlets are not obstructed	No obstruction by the inlets as the park is well maintained	Pass
	no erosion at inlets	None	Pass
	pre-treatment is in place and functioning	N/A	Pass
	structurally sound	Yes	Pass
	no safety concerns	None	Pass
4. Bioretention Bed	surface area matches design (89 sq m)	111 sq m per as-built	Pass
	no slide slope erosion	Minimal side slope erosion – mainly due to foot traffic	Pass
	bed is properly graded, no excessive settlement	No settlement visible – bioretention seems properly graded	Pass
	no bed erosion	No bed erosion	Pass
	no sediment caking or build-up on the surface	No sediment building up or caking	Pass
	presence of debris and trash (less than 5% coverage)	Minimal garbage present (<5%)	Pass
	soil is a loamy sand consistency	Soil is loamy sand mainly near the downstream end where the catchbasin is located. Upstream end is native soils.	Pass
	no standing water	Underdrain still flowing but no standing water present.	Pass
	mulch depth is 50-100 mm	Mulch depth < 50 mm	Fail

5. Underdrain	underdrain is at the correct height (600 mm from top of overflow structure)		
6. Vegetation	vegetation cover is > 75 %	Rain garden well covered by vegetation	Pass
	vegetation is in good health and established	Grasses are well and alive but the black eyed susans are completely dry/dead.	Fail
7. Overflow	in place and at the correct elevation (inverts are 200 mm above the bioretention surface)	Overflow was flush with soil which causes short circuiting and eliminates surface ponding.	Fail
	free of debris and clogging	No debris present at overflow catchbasin therefore, no potential clogging.	Pass
Comments: The most recent visual inspection was made on November 4th, 2013 and overall the practice ***fails*** the visual inspection. This is due to lack of ponding depth resulting in reduced total storage capacity. However, the site is overdesigned and this maybe compensating for the eliminated surface storage. **Recommendation: In future, soils should be lowered to increase surface ponding depth and raise the overflow off of the ground surface.**			

Table 3. Testing Protocol: Landscaping Survey			
Assessment Item	**Metric / Passing Threshold**	**Result**	**Pass / Fail**
1. What percentage of the ground is covered?	80%	80%	Pass
2. What percentage of plants is invasive/ undesirable?	5%	0%	Pass
3. What percentage of planted species has died?	5%	4%	Pass
4. What percentage of the species is thriving? Ex. ranked 3 or higher	80%	95%	Pass
5. Does the site meet aesthetic goals? Ex. colour, year round interest, clean formal appearance and planter visibility	Yes	Yes	Pass
Comments: Landscaping assessments were conducted in September 2013. Excellent flower display and formal appearance. Overall, the site ***passes*** the landscaping survey protocol. **Recommendation: Shift to post establishment maintenance program.**			

Table 4. Testing Protocol: Soil Testing LEVEL 2

Assessment Item	Metric / Passing Threshold	Result	Pass / Fail
1. Texture: Sand 2.0 – 0.075 mm dia.: Silt and Clay < 0.05mm dia., sieve 270	86 - 92 % by weight 8- 12 % by weight	80.5 % by weight 19.5 % by weight	Fail
2. Organic content:	3- 5% by dry weight	1.15% by weight	Fail
3. Cationic exchange capacity (CEC):	>10 meq/100 g	23 meq/100 g	Pass
4. Soil Acidity:	5.5 - 7.5 pH	7.2 pH	Pass

Comments: Overall the facility ***fails*** the soil testing protocol as it does not meet the required objectives for texture and organic content. However, the soil texture results are very close to the acceptable metric range and may not even be a functional issue.

Recommendation: Further investigation needs to be done to determine the mixing strategy that was used for the bioretention soil media. A failed soil test could trigger replacement if under warranty or further observation and testing through water level monitoring. In order to compensate for the low organic matter, shredded hardwood mulch can be added to the surface which will supply nutrients overtime. However, some studies have found that the addition of organic matter results in nutrient export (phosphorus and nitrate) into the effluent quality. The addition of organic matter is only recommended if vegetation is unable to survive but if the vegetation seems in optimal health, the low organic content is sufficient for vegetation to survive.

Table 5. Testing Protocol: As-Constructed Survey LEVEL 2

Assessment Item	Metric / Passing Threshold	Result	Pass / Fail
1. Contributing drainage area:	1, 800sq m	1, 877 sq m	Pass
2. Bioretention area	89 sq m	111 sq m	Pass
3. Surface storage volume	-	-	-
4. Subsurface Storage Volume above the underdrain invert	-	-	-
5. Subsurface storage below the underdrain invert	-	-	-
6. Total storage capacity (water quality storage volume)	47.17 cu m	85.5 cu m	Pass
7. Inlet grades:	inlets are in the correct	The inlet grade is slightly	Pass

	location as per design plans and allow positive drainage from the catchment area	lower than the curb cut elevation ensuring positive drainage into the biorenteion area.	

Comments and Corrective Actions Taken:

- The as-built drainage area closely matches the design plans with an additional 77 sq m of surface area.
- The as-built bioretention area is slightly larger than the design plan with an additional 22 sq m.
- The as-built total storage capacity is twice the designed capacity with an additional 38 cu m.

Overall, the facility ***passes*** the as-constructed survey protocol as it matches if not exceeds the contributing drainage area, bioretention area and the total storage capacity.

Recommendation: No recommendations at this time

Table 6. Testing Protocol: Infiltration Testing LEVEL 2

Assessment Item	**Metric / Passing Threshold**	**Result**	**Pass / Fail**
1. Infiltration Rate	> 25 mm/hr	Ranges from 3 mm/hr to 9 mm/hr with an average infiltration rate of 7 mm/hr	Inconclusive*

Comments: The Guelph Permeameter test was performed on November 4th, 2013 in three spots spanning the length of the bioretention facility and the results were averaged as presented above. The results provided above are the in-situ saturated hydraulic conductivity measurements which equal the infiltration rate. The sorptivity is influenced by the initial and final moisture contents. As the moisture content approaches saturation, sorptivity tends to zero and the infiltration rate equals to the field saturated hydraulic conductivity[xii].

*NOTE: THE INFILTRATION TEST WAS PERFORMED WITHIN THE 24 HOUR NO PRECIPITATION WINDOW. HOWEVER, WHEN THE INFITLRATION TEST WAS BEING PERFORMED, THE UNDERDRAIN WAS STILL FLOWING WHICH INDICATES SATURATED SUBSOILS. THE SUBSOILS HAVE 48 HOURS TO DRAIN DOWN PER DESIGN SPECIFICATIONS AND THE MEASURED SATURATED HYDRAULIC CONDUCTIVITY SEEMS VERY LOW DOR SUCH SOIL COMPOSITION. THE 24 HOURS NO PRECIPITATION WINDOW SHOULD BE UPDATED TO 48 HOURS IF NOT 72 HOURS TO ENSURE UNSATURATED SOILS AT THE TIME OF THE TEST.

Recommendation: Infiltration tests should be performed again in summer 2013 during extremely dry periods with atleast 48-72 hours of no precipitation. The Guelph Permeameter is a simple and fast method for performing infiltration tests, however, it is intended for native soils and any inaccuracies for use in bioretention soils are currently unknown. It is recommended to duplicate the infiltration results with other test methods such as the Double Ring Infiltrometer for comparison and higher accuracy.

Table 7. Testing Protocol: Continuous Water Level Monitoring LEVEL 3

Assessment Item	**Metric / Passing Threshold**	**Result**	**Pass / Fail**
1 – Surface Drawdown Time (hrs)	24 hrs		

2. Subsurface Drawdown Time (hrs)	48 hrs	Ranges from 374 hrs to 1030 hr with an average of 576 hrs	Fail

Comments: The as-constructed bioretention facility ***fails*** the water level monitoring test as the subsurface drawdown time is far more than 48 hours. The water level analysis was performed on rain events greater than 10 mm and the assessment of surface ponding drawdown rates and times was neglected due to inadequate data. Only above and below drain drawdown rates and times were calculated based on this data. As a lesson learned, additional information is needed to perform a complete analysis including surface ponding capacity and duration as recommended below.

Recommendation: In addition to the subsurface observational well, a second observational well should be added to the surface to monitor surface ponding and duration to make certain that the as-constructed facility meets the 24 hours design criteria.

Discussion

All testing protocols were completed by November 2013. O' Connor Park ***passes*** most testing protocols except for the soil testing protocol. The key assessment items identified in these individual protocols are discussed below:

- *Visual Inspection* – The site seems to have an acceptable appearance however additional mulch needs to be added to ensure 50-100 mm depth.
- *Soil Testing* – The soil mixture does not meet the optimum texture composition for Coarse sand and silt/clay particles without having to replace the entire soil matter. There is a low organic content which can be compensated for with the addition of organic matter such as leaf matter or grass clippings into the top layer of the soil to ensure adequate nutrient supply for plant survival.

In addition to the visual inspection, other testing protocols assist in evaluating the site better with respect to grading and the need for positive drainage into the bioretention areas. All protocols need to be assessed as a whole to truly determine the function of the LID site.

Application of Certification Protocols to Portico Church

Planted Bioretention Cell at Portico Church in 2011

Portico Community Church is located just off of Queen Street South in Mississauga Ontario. In 2009, Portico demonstrated their dedication to environmental stewardship by constructing one of the first green parking lots in the Credit River watershed. Green infrastructure implemented at Portico Church includes permeable pavement, bioswale and a central bioretention cell. The central bioretention cell is designed as such that it accepts concentrated flow runoff generated from the adjacent parking lot and enters the bioretention through a series of curb cuts and discharges to a sub-drain or a perforated pipe. The bioswale media is clayey sand where as the native soils are clay. The bioswale is planted with native woodland and ornamental shrubs topped with shredded hardwood mulch.

The draft certification protocols were piloted at seven bioretention sites in the Credit River Watershed over 2012 and 2013. Certification level 3 and the associated protocols were applied in an effort to compare the as-constructed to the original design. Of the seven protocol methods, six were applied to Portico Church. Synthetic runoff testing was not applied as there was not a convenient water source nearby to conduct the test. Also, outlet flow and water quality monitoring has not been applied due to budget constraints. The protocols applied and pass/fail performance for each is summarized in **Table 1**.

Table 1. Summary of Certification Protocols for Portico Church

Testing Protocol	Timeframe Test Performed	Pass/Fail
Checklist Inspection	Conducted October 29th, 2013	Fail
Vegetation Surveys	completed in September 2013	Fail
Soil Testing	July 2012	Pass
As-Constructed Survey	June 2012	Pass
Infiltration Testing or Synthetic Runoff	Test performed on October 29th, 2013	Pass
Water Level Monitoring	Data collected from Oct 2012 to Oct 2013 and analysis has been completed.	Pass
Water Flow & Quality Monitoring	Not applied	-

As summarized in Table 2, Portico Church ***passes*** the soil test, the elevation survey, infiltration testing, and water level monitoring. However, the site currently fails the visual inspection and vegetation survey protocols. The summary report hereon outlines the test or survey findings for each protocol and provides recommendations that need to be implemented to ensure that the LID practice passes all assumption protocols and is constructed to design before the municipality takes assumption of the practice.

Piloting these certification protocols provide a guidance tool and a standard procedure that business/property owners and municipalities can employ before taking ownership of an LID practice. A thorough certification protocol reduces the risk to the owner that they are assuming a facility that is functioning properly and will not require costly near or long term repairs. These certification protocols are particularly important for stormwater management facilities. A 2007 survey of southern Ontario municipalities found that certification and monitoring protocols for stormwater ponds to be weak or non-existent[xiii]. This has resulted in many instances of ponds that have been assumed by the municipality that do not meet design requirements. A study of 98 ponds in the Lake Simcoe Conservation Area found that nearly half the ponds failed to meet their design level of service.[xiv] Both studies recommended more rigorous certification protocols before assumption, including at a minimum an as-constructed survey. More detailed results on each of the protocols are provided in **Tables 2 - 7**.

Table 2. Testing Protocol: Visual Inspection LEVEL 1

Assessment Item	Metric / Passing Threshold	Result	Pass / Fail
1. Drainage Area	Contributing drainage area matches the design plans	Yes	Pass
	Drainage area is stabilized and well maintained	Yes	Pass
2. Inlets	Inlets are not obstructed	Inlets are obstructed by sediment building at curb cuts and higher grass/weeds	Fail
	no erosion at inlets	No erosion	Pass
	pre-treatment is in place and functioning	No riprap pre-treatment	N/A
	structurally sound	Yes	Pass
	no safety concerns	None	Pass
4. Bioretention Bed	surface area matches design (253 sq m)	As-built survey bioretention area = 235 sq m	Pass
	no slide slope erosion	None	Pass
	bed is properly graded, no excessive settlement	Bed seems properly graded with no settlement visible.	Pass
	no bed erosion	Minimal	Pass
	no sediment caking or build-up on the surface	None	Pass
	presence of debris and trash (less than 5% coverage)	Minimal garbage present (<5%)	Pass
	soil is a loamy sand consistency	Yes	Pass
	no standing water	None	Pass
	mulch depth is 50-100 mm	~ 20 mm. Many spots of soil exposed with no mulch depth.	Fail
5. Underdrain	underdrain is at the correct		Pass

	height		
6. Vegetation	vegetation cover is > 75 %	Yes	Pass
	vegetation is in good health and established	Yes	Pass
7. Overflow	in place and at the correct elevation (inverts are 200 mm above the bioretention surface)	Yes	
	free of debris and clogging	No debris or clogging present	Pass

Comments: The most recent visual inspection was made on October 29th, 2013.

Recommendation: The site passes the visual inspection with the exception of inlet blockage and mulch depth. The following actions are recommended:

- **Regrading at the inlet to lower the soil and vegetation and removal of sediment.**
- **Add mulch to maintain a depth of at least 50 mm.**

Table 3. Testing Protocol: Landscaping Survey

Assessment Item	**Metric / Passing Threshold**	**Result**	**Pass / Fail**
1. What percentage of the ground is covered?	80%	80%	Pass
2. What percentage of plants is invasive/ undesirable?	5%	5%	Pass
3. What percentage of planted species has died?	5%	10%	Fail
4. What percentage of the species is thriving? Ex. ranked 3 or higher	80%	50%	Fail
5. Does the site meet aesthetic goals? Ex. colour, year round interest, clean formal appearance and planter visibility	Yes	No	Fail

Comments: Landscaping assessments were conducted in September 2013.

Recommendation:

- ✓ **Replace dead plants with different species**
- ✓ **Replace struggling plants with different species**
- ✓ **Replace unattractive plants with species that meet aesthetic goals**

Table 4. Testing Protocol: Soil Testing LEVEL 2

Assessment Item	**Metric / Passing Threshold**	**Result**	**Pass**

			/ Fail
1. Texture: Sand 2.0 – 0.075 mm dia.: Silt and Clay < 0.05mm dia., sieve 270	86 - 92 % by weight 8- 12 % by weight	90.5 % by weight 9.5% by weight	Pass
2. Organic content:	3- 5% by dry weight	0.84 % by weight	Fail
3. Cationic exchange capacity (CEC):	>10 meq/100 g	11 meq/100 g	Pass
4. Soil Acidity:	5.5 - 7.5 pH	7.0 pH	Pass

Comments: Overall, the site ***passes*** the soil testing protocol except for the organic content objective. The soil was not amended with compost matter but instead shredded mulch and plant matter was added which will add to the organic content over time. Some studies have found that the addition of organic matter results in nutrient export (phosphorus and nitrate) into the effluent quality. The addition of compost matter is only recommended if vegetation is unable to survive but if the vegetation seems in optimal health, the low organic content is sufficient for vegetation to survive.

Recommendation: No soil alterations are recommended at this time.

Table 5. Testing Protocol: As-Constructed Survey LEVEL 2

Assessment Item	**Metric / Passing Threshold**	**Result**	**Pass / Fail**
1. Contributing drainage area:	7,500 m^2	7,650 m^2	Pass
2. Bioretention area	225 m^2	235 m^2	Pass
3. Surface storage volume	-	14 m^3	-
4. Subsurface Storage Volume above the underdrain invert	171 m^3	216 m^3	Pass
5. Subsurface storage below the underdrain invert	132 m^3	-15.3 m^3	Pass
6. Total storage capacity (water quality storage volume)	304 m^3	216 m^3	Pass
7. Inlet grades:	Inlets are in the correct location as per design plans and allow positive drainage from the catchment area	The curb inlet elevations are lower as compared to the contributing drainage area elevations ensuring positive drainage into the system	Pass

Comments and Corrective Actions Taken:

- The as-constructed contributing drainage area is increased by an additional 2,150 m^2 larger as compared to the design plan out of which approximately 500 m^2 is landscaped areas.

- The as-constructed bioretention area almost matches the design plan.
- The as-constructed subsurface storage volume above the underdrain is increased by 45 cu m.
- There is no subsurface storage below the underdrain which is recommended in low infiltration native soils provide the adequate draw-down time and exfiltration into native soils.
- The total storage capacity is smaller by 88 m^3 which is primarily due to the larger contributing area; however, the facility still functions properly and treats the 18 mm as opposed to the 25 mm design storm event.

Overall, the bioretention facility ***passes*** the as-constructed survey protocol. The storage capacity is slightly smaller than the design but the facility still meets the MOE's required minimum sizing for Level 1 Enhanced Protection.

Recommendation: No recommendations at the moment.

Table 6. Testing Protocol: Infiltration Testing LEVEL 2			
Assessment Item	**Metric / Passing Threshold**	**Result**	**Pass / Fail**
1. Infiltration Rate	> 25 mm/hr	Ranges from 118 mm/hr to 158 mm/hr with an average of 136 mm/hr	Pass

Comments: The Guelph Permeameter test was performed on October 29th, 2013 in three spots spanning 3-5 m around the catchbasin overflow within the bioretention facility and the results were averaged as presented above. Overall, the facility ***surpasses*** the infiltration testing protocol as the in-situ infiltration rates are higher than the minimum threshold of 25 mm/hr. The results provided above are the in-situ saturated hydraulic conductivity measurements which equal the infiltration rate. The sorptivity is influenced by the initial and final moisture contents. As the moisture content approaches saturation, sorptivity tends to zero and the infiltration rate equals to the field saturated hydraulic conductivity[xv].

Recommendations: Soil composition and infiltration tests confirmed that the bioretention soil mix is performing at the proper infiltration rate. At this time, no soil alterations are recommended.

Table 7. Testing Protocol: Continuous Water Level Monitoring LEVEL 3			
Assessment Item	**Metric / Passing Threshold**	**Result**	**Pass / Fail**
1 – Surface Drawdown Time (hrs)	24 hrs	19 hours	Pass
2. Subsurface Drawdown Time (hrs)	48 hrs	Ranges from 6 hrs to 32 hrs with an average 22.7 hrs.	Pass

Comments: The as-constructed bioretention facility ***passes*** the water level monitoring test as the surface drawdown time is less than 24 hours and the subsurface drawdown time is less than 48 hours.

Recommendation: The site is performing within the design specifications and no further alterations are recommended.

Discussion
All testing protocols were completed by November 2013. Portico Church site ***passes*** all testing protocols except for the visual inspection and the vegetation survey. The key assessment items identified in these individual protocols are discussed below:

- *Visual Inspection* – The inlets are seriously blocked due to sediment build up and tall grass which may impede positive drainage into the bioretention cell and they need to be cleared. Additional mulch needs to be added to a depth of atleast 50-100 mm to cover any exposed bare soils.
- *Landscaping Survey* – The current vegetation survey indicates that the site does not meet the required aesthetic appeal and any dead, struggling or unattractive plants need to be replaced.
- *Soil Testing* – The bioretention soil mixture does not meet the organic content required to sustain plant health and shredded mulch and plant matter was added which will contribute to the organic content overtime.
- *As-built Survey* – There are some uncertainties related to the subsurface storage below the underdrain which results in a reduction of the total storage capacity.

In addition to the visual inspection, other testing protocols assist in evaluating the site better with respect to grading and the need for positive drainage into the bioretention areas. It is important to evaluate the results for all testing protocols side by side from a visual inspection to water level monitoring and truly analyze whether the constructed LID facility meets the design requirements.

Application of Certification Protocols to Terra Cotta Rain Garden

Terra Cotta Conservation Area (TCCA) is a 485 naturalized area located within the village of Terra Cotta. A rain garden was constructed next to the Visitors Welcome Centre similar to what would typically be constructed on a residential property. The rain garden accepts concentrate runoff from the Welcome Center's rooftop through a roof leader. The bioretention soil mix is composed of silt and organic matter where the native soils were clayey loamy silt with an infiltration rate of 14 mm/hr for the native soils. The plant community is native woodland topped with shredded hardwood mulch.

Terra Cotta Rain Garden

The draft certification protocols were piloted at seven bioretention sites in the Credit River Watershed over 2012 and 2013. Certification level 3 and the associated protocols were applied at Terra Cotta's Rain Garden in an effort to compare the as-constructed to the original design. Of the seven protocol methods, six were applied to Terra Cotta. Synthetic runoff testing was not applied as there was not a convenient water source nearby to conduct the test. Also, outlet flow and water quality monitoring has not been applied due to budget constraints. The protocols applied and pass/fail performance for each is summarized in **Table 1**.

Table 1. Summary of Assumption Protocols for Terra Cotta

Testing Protocol	Timeframe Test Performed	Pass/Fail
Checklist Inspection	Conducted November 4th, 2013	Fail
Vegetation Surveys	Final vegetation survey was conducted in September 2013	Pass
Soil Testing	July 2012	Fail
As-Constructed Survey	June 2012	Fail
Infiltration Testing or Synthetic Runoff	Test performed on November 4th, 2013	Fail
Water Level Monitoring	Data collected from Oct 2012 to Oct 2013	Pass
Water Flow & Quality Monitoring	Not Applied	-

As summarized in Table 1, Terra Cotta Rain Garden ***passes*** the vegetation survey, infiltration testing, and water level monitoring. However, the site currently ***fails*** the visual inspection, soil test, infiltration testing and elevation survey protocols in comparison to the original design specifications and details. The summary report hereon outlines the test or survey findings for each protocol and provides recommendations that need to be implemented to ensure that the LID practice passes all assumption protocols and is constructed to design.

Piloting these certification protocols provide a guidance tool and a standard procedure that business/property owners and municipalities can employ before taking ownership of an LID practice. A thorough certification protocol reduces the risk to the owner that they are assuming a facility that is functioning properly and will not require costly near or long term repairs. These certification protocols are particularly important for stormwater management facilities. A 2007 survey of southern Ontario municipalities found that certification and monitoring protocols for stormwater ponds to be weak or non-existent[xvi]. This has resulted in many instances of ponds that have been assumed by the municipality that do not meet design requirements. A study of 98 ponds in the Lake Simcoe Conservation Area found that nearly half the ponds failed to meet their design level of service.[xvii] Both studies recommended more rigorous certification protocols before assumption, including at a minimum an as-constructed survey. More detailed results on each of the protocols are provided in **Tables 2 - 7**.

Table 2. Testing Protocol: Visual Inspection LEVEL 1

Assessment Item	Metric / Passing Threshold	Result	Pass / Fail
1. Drainage Area	Contributing drainage area matches the design plans	Design = 120 sq m As-built = 120 sq m	Pass
	Drainage area is stabilized and well maintained	Yes	Pass
2. Inlets	Inlets are not obstructed	No obstructions covering the facility's' inlet pipe	Pass
	no erosion at inlets	Minimal erosion, mainly foot traffic.	Pass
	pre-treatment is in place and functioning		
	structurally sound	Yes	Pass
	no safety concerns	None	Pass
4. Bioretention Bed	surface area matches design (135 sq m)		
	no slide slope erosion	None evident.	Pass
	bed is properly graded, no excessive settlement	Yes	Pass
	no bed erosion	no bed erosion found	Pass
	no sediment caking or build-up on the surface	no sediment build-up	Pass
	presence of debris and trash (less than 5% coverage)	Major debris accumulation. The entire rain garden is covered with leave debris.	Fail
	soil is compost amended silt till	Yes	Pass
	no standing water	No	Pass
	mulch depth is 50-100 mm	< 50 mm	Fail
5. Underdrain	underdrain is at the correct height	N/A	N/A
6. Vegetation	vegetation cover is > 75 %	Low vegetation cover	Fail
	vegetation is in good health and established	Plants are in good health	Pass
7. Overflow	in place and at the correct elevation	Yes	Pass

	free of debris and clogging	Yes	Pass

Comments: The most recent visual inspection was made on November 4th, 2013. Overall, the site ***passes*** the visual inspection protocol and necessary steps need to be taken to ensure the facility passes this protocol.

Recommendation: At the time of the visit, the bioretention facility is entirely covered with leave debris by atleast 30 mm. The leave debris needs to be removed to ensure the bioretention facility surface is exposed to receive runoff. During the site visit, many spots of bare soil were observed and a layer of mulch needs to be added to maintain the 50 mm layer.

Table 3. Testing Protocol: Landscaping Survey

Assessment Item	**Metric / Passing Threshold**	**Result**	**Pass / Fail**
1. What percentage of the ground is covered?	80%	80%	Pass
2. What percentage of plants is invasive/ undesirable?	5%	5%	Pass
3. What percentage of planted species has died?	5%	0%	Pass
4. What percentage of the species is thriving? Ex. ranked 3 or higher	80%	84%	Pass
5. Does the site meet aesthetic goals? Ex. colour, year round interest, clean formal appearance and planter visibility	Yes	Yes	Pass

Comments: Landscaping assessments were conducted in September 2013. Site looks good, naturalizing well.

Recommendation: Shift to post establishment maintenance program.

Table 4. Testing Protocol: Soil Testing LEVEL 2

Assessment Item	**Metric / Passing Threshold**	**Result**	**Pass / Fail**
1. Texture: Sand 2.0 – 0.075 mm dia.: Silt and Clay < 0.05mm dia., sieve 270	The soil is compost amended silt till mix.	53 % by weight 47 % by weight	N/A
2. Organic content:	3- 5% by dry weight	0.72 % by weight	Fail

3. Cationic exchange capacity (CEC):	>10 meq/100 g	11 meq/100 g	Pass
4. Soil Acidity:	5.5 - 7.5 pH	7.1 pH	Pass
Comments: Overall, the facility ***passes*** the soil testing protocol as it does not meet the required objectives for texture and organic content and additional steps need to be taken to ensure it passes this protocol. Please note that this facility represents a rain garden as opposed to a large scale bioretention facility. The main difference between the two is that a rain garden is a residential application where the soils are generally amended with compost materials. An engineered bioretention cell treats a large contributing area such as a parking lot or a road. **Recommendation: Further investigation needs to be done to determine the mixing strategy that was used for the bioretention soil media. A failed soil test could trigger replacement if under warranty or further observation and testing through water level monitoring. In order to compensate for the low organic matter, shredded hardwood mulch can also be added to the surface which leaches organics over time. However, low organic matter only needs to be adjusted if the plants are unable to survive due to inadequate nutrient supply, which is not the case for this site.**			

Table 5. Testing Protocol: As-Constructed Survey LEVEL 2			
Assessment Item	**Metric / Passing Threshold**	**Result**	**Pass / Fail**
1. Contributing drainage area:	120 sq m	120 sq m	Pass
2. Bioretention area	15 sq m	15 sq m	Pass
3. Surface storage volume	3 cu m	3 u m	Pass
4. Subsurface Storage Volume above the underdrain invert	5.3	5.3	Pass
5. Subsurface storage below the underdrain invert	N/A	N/A	N/A
6. Total storage capacity (water quality storage volume)	8.3 cu m	8.3 cu m	Pass
7. Inlet grades:	inlets are in the correct location as per design plans and allow positive drainage from the catchment area	-	-
Comments and Corrective Actions Taken: • The as-built contributing drainage area and bioretention area equally matching the design plans. • The surface storage volume was designed to provide 3 cu m however per as-built, no surface storage volume is provided. • Given the LID facility is very small; the total storage capacity was also reduced by 3 cu m per the as-built survey.			

Overall, the facility ***passes*** the as-constructed survey protocol as it is undersized due to no surface storage provided which results in reduction in total storage capacity. The following recommendation needs to be implemented to ensure that the storage capacity is adequate and matches the design specification. **Recommendation: The bioretention bed should be regraded and perhaps some material should be removed to ensure the required surface ponding volume as designed is achieved.**

Table 6. Testing Protocol: Infiltration Testing LEVEL 2			
Assessment Item	**Metric / Passing Threshold**	**Result**	**Pass / Fail**
1. Infiltration Rate	> 25 mm/hr	Ranges from 6 mm/hr 17 mm/hr with an average infiltration rate of 10 mm/hr	Fail
Comments: The Guelph Permeameter test was performed on November 4th, 2013 in three spanning the bioretention practice and near the observation well. Overall, the facility ***fails*** the infiltration capacity protocol as it does not meet the minimal 25 mm/hr passing threshold. The results provided above are the in-situ saturated hydraulic conductivity measurements which equal the infiltration rate. Unlike **Recommendation: Level 3 continuous water level monitoring is recommended to evaluate the surface and subsurface drawdown rates. The Guelph Permeameter is a simple and fast method for performing infiltration tests, however, it is intended for native soils and any inaccuracies for use in bioretention soils are currently unknown. It is recommended to duplicate the infiltration results with other test methods such as the Double Ring Infiltrometer for higher accuracy. Most importantly, the metric threshold needs to be reconsidered for rain garden applications that use amended compost.**			

Table 7. Testing Protocol: Continuous Water Level Monitoring LEVEL 3			
Assessment Item	**Metric / Passing Threshold**	**Result**	**Pass / Fail**
1 – Surface Drawdown Time (hrs)	24 hrs	-	-
2. Subsurface Drawdown Time (hrs)	48 hrs	Ranges from 1.2 hrs to 3.3 hr with an average of 2.4 hrs	Pass
Comments: The as-constructed bioretention facility ***passes*** the water level monitoring test as the subsurface drawdown time is less than 48 hours. The water level analysis was performed on rain events greater than 10 mm and the assessment of surface ponding drawdown rates and times was neglected due to inadequate data. As a lesson learned, additional information is needed to perform a complete analysis including surface ponding capacity and duration as recommended below. **Recommendation: In addition to the subsurface observational well, a second observational well should be added to the surface to monitor surface ponding and duration to make certain that the as-constructed facility meets the 24 hours design criteria.**			

Discussion

All testing protocols were completed by November 2013. Terra Cotta Rain Garden ***passes*** most of the testing protocols if the above mentioned recommendations are implemented. The key assessment items identified in these individual protocols are discussed below:

- *Visual Inspection* – The last visual inspection was conducted on November 4th and during that visit the entire bioretention facility was covered with leave debris by atleast 30 mm. The leave debris needs to be removed to ensure the bioretention facility surface is exposed to receive runoff. During the site visit, many spots of bare soil were observed and a layer of mulch needs to be added to maintain the 50 mm layer.
- *Soil Testing* – This site is a rain garden application where the soils are compost amended with silt till mix. The current metric for bioretention soil mixture does not apply in this case and needs to be revisited. There is a low organic content which can be compensated for with the addition of shredded mulch which slowly releases nutrients/organic materials overtime to ensure adequate nutrient supply for plant survival.

To perform a true assessment of the facility, a visual inspection along is not adequate. The subsurface issues which are overlooked during a visual inspection including soil mixture, organic matter and as-constructed design practices can only be determined with these additional inspections and tests.

Application of Certification Protocols to Unitarian Church


Unitarian Congregation Church Bioretention Cell

The Unitarian Congregation in Mississauga (UCM) is located on South Service Road between Mary Fix and Wolfedale Creeks, two urban and degraded creeks within the Credit River Watershed that drain into Lake Ontario. Green infrastructure at Unitarian Congregation Church includes a bioretention which is designed as such that it accepts sheet flow runoff generated from the adjacent parking lot that enters the bioretention cell through a series of curb cuts. The bioretention facility does not have a sub-drain/perforated pipe; however there is an overflow catchbasin that goes directly into the existing storm sewer.

The draft certification protocols were piloted at seven bioretention sites in the Credit River Watershed over 2012 and 2013. The draft certification protocols were piloted at seven bioretention sites in the Credit River Watershed over 2012 and 2013. Certification level 3 and the associated protocols were applied at Unitarian Church in an effort to compare the as-constructed to the original design. Of the seven protocol methods, six were applied to Unitarian Church. Synthetic runoff testing was not applied as there was not a convenient water source nearby to conduct the test. Also, outlet flow and water quality monitoring has not been applied due to budget constraints. The protocols applied and pass/fail performance for each is summarized in **Table 1**.

Table1. Summary of Assumption Protocols for Unitarian Church		
Testing Protocol	**Timeframe Test Performed**	**Pass/Fail**
Checklist Inspection	Conducted October 29th, 2013	Pass
Vegetation Surveys	Final vegetation survey conducted in September 2013	Pass
Soil Testing	July 2012	Fail
As-Constructed Survey	June 2012	Fail
Infiltration Testing or Synthetic Runoff	Test performed on October 29th, 2013	Pass
Water Level Monitoring	Data collected from Oct 2012 to Oct 2013.	Fail
Water Flow & Quality Monitoring	Not applied	-

As summarized in Table 1, Unitarian Congregation Church ***passes*** the visual inspection, vegetation survey and infiltration testing. However, the site currently ***fails*** the soil test and as-constructed survey protocols and the water level monitoring protocols in comparison to the original design specifications and details. The summary report hereon outlines the test or survey findings for each protocol and provides recommendations that need to be implemented to ensure that the LID practice passes all assumption protocols and is constructed to design.

Piloting these certification protocols provide a guidance tool and a standard procedure that business/property owners and municipalities can employ before taking ownership of an LID practice. A thorough certification protocol reduces the risk to the owner that they are assuming a facility that is functioning properly and will not require costly near or long term repairs. These certification protocols are particularly important for stormwater management facilities. A 2007 survey of southern Ontario municipalities found that certification and monitoring protocols for stormwater ponds to be weak or non-existent[xviii]. This has resulted in many instances of ponds that have been assumed by the municipality that do not meet design requirements. A study of 98 ponds in the Lake Simcoe Conservation Area found that nearly half the ponds failed to meet their design level of service.[xix] Both studies recommended more rigorous certification protocols before assumption, including at a minimum an as-constructed survey. More detailed results on each of the protocols are provided in **Tables 2 - 7**.

Table 2. Testing Protocol: Visual Inspection LEVEL 1			
Assessment Item	**Metric / Passing Threshold**	**Result**	**Pass / Fail**
1. Drainage Area	Contributing drainage area matches the design plans	Design = 2300 sq m As-built = 2767 sq m	
	Drainage area is stabilized and well maintained	Satisfactory	Pass
2. Inlets	Inlets are not obstructed	No obstructions covering the facility curb inlets	Pass
	no erosion at inlets	Minimal erosion, mainly foot traffic.	Pass
	pre-treatment is in place and functioning	N/A	-
	structurally sound	Yes	Pass
	no safety concerns	None	Pass
4. Bioretention Bed	surface area matches design (135 sq m)	Design = 250 sq m As-built = 227.5 sq m	Pass
	no slide slope erosion	minor side slope erosion, related to foot traffic	Pass
	bed is properly graded, no excessive settlement	No settlement observed	Pass
	no bed erosion	no bed erosion found	Pass
	no sediment caking or build-up on the surface	no sediment build-up	Pass
	presence of debris and trash (less than 5% coverage)	Minimal debris (<5%)	Pass
	soil is a loamy sand consistency	Yes	Pass
	no standing water	No	Pass
	mulch depth is 50-100 mm	50mm +	Pass
5. Underdrain	underdrain is at the correct height		
6. Vegetation	vegetation cover is > 75 %	Vegetation cover >75%	Pass
	vegetation is in good health	Yes	Pass

	and established		
7. Overflow	in place and at the correct elevation		
	free of debris and clogging	Geotextile covering catchbasin overflow with some mulch	Fail

Comments: The most recent visual inspection was made on October 29th, 2013. Overall the bioretention facility ***passes*** the visual inspection.

Recommendation: The overflow catchbasin needs to be cleared of debris and obstruction. As of now a geotextile fabric covers the catchbasin which may obstruct overflow causing the facility to pond for a longer period of time. The fabric should be removed and adding a layer of rock around the catchbasin is recommended to trap the debris and keep the overflow grate free of obstruction.

Table 3. Testing Protocol: Landscaping Survey

Assessment Item	**Metric / Passing Threshold**	**Result**	**Pass / Fail**
1. What percentage of the ground is covered?	80%	85%	Pass
2. What percentage of plants is invasive/ undesirable?	5%	3%	Pass
3. What percentage of planted species has died?	5%	0%	Pass
4. What percentage of the species is thriving? Ex. ranked 3 or higher	80%	100%	Pass
5. Does the site meet aesthetic goals? Ex. colour, year round interest, clean formal appearance and planter visibility	Yes	Yes	Pass

Comments: Landscaping assessments were conducted in September 2013. Full healthy plants, but layout is jumbled.

Recommendation: Shift to post establishment maintenance program.

Table 4. Testing Protocol: Soil Testing LEVEL 2

Assessment Item	**Metric / Passing Threshold**	**Result**	**Pass / Fail**
1. Texture: Sand 2.0 – 0.075 mm dia.: Silt and Clay	 86 - 92 % by weight 8- 12 % by weight	 53 % by weight 47 % by weight	N/A

< 0.05mm dia., sieve 270			
2. Organic content:	3- 5% by dry weight	0.72 % by weight	Fail
3. Cationic exchange capacity (CEC):	>10 meq/100 g	11 meq/100 g	Pass
4. Soil Acidity:	5.5 - 7.5 pH	7.1 pH	Pass

Comments: Overall the facility ***passes*** the soil testing protocol except the organic content item. The soil texture criteria do not apply in this case as the bioretention mix was amended with the native soils which were silty clay.

Recommendation: In order to compensate for the low organic matter, shredded hardwood mulch can be added to the surface which leaches nutrients overtime. However, some studies have found that the addition of organic matter results in nutrient export (phosphorus and nitrate) into the effluent quality. The addition of organic matter is only recommended if vegetation is unable to survive but if the vegetation seems in optimal health, the low organic content is sufficient for vegetation to survive.

Table 5. Testing Protocol: As-Constructed Survey LEVEL 2

Assessment Item	**Metric / Passing Threshold**	**Result**	**Pass / Fail**
1. Contributing drainage area:	2300 sq m	2767 sq m	Pass
2. Bioretention area	250 sq m	227.5 sq m	Fail
3. Surface storage volume	50 cu m	25 cu m	Fail
4. Subsurface Storage Volume above the underdrain invert	-	-	
5. Subsurface storage below the underdrain invert	-	-	
6. Total storage capacity (water quality storage volume)	300 cu m	234 cu m	Fail
7. Inlet grades:	inlets are in the correct location as per design plans and allow positive drainage from the catchment area		

Comments and Corrective Actions Taken:

- The as-built contributing drainage area was larger than the design plan with an additional 467 sq m.
- The as-built bioretention area was smaller by 22 sq m as compared to the design plans.
- The surface storage volume was reduced by 25 cu m per as-built survey.
- The total storage capacity was also reduced by 66 cu m per the as-built survey.

Overall, the facility ***fails*** the as-constructed survey protocol as it is undersized due to the larger contributing drainage area which was not accounted for in the LID design plans.

Recommendation: No recommendations at the moment

Table 6. Testing Protocol: Infiltration Testing LEVEL 2			
Assessment Item	**Metric / Passing Threshold**	**Result**	**Pass / Fail**
1. Infiltration Rate	> 25 mm/hr	Ranges from 2 mm/hr to 62 mm/hr with an average of 26 mm/hr	Pass

Comments: The Guelph Permeameter test was performed on October 29th, 2013 in three spots near spanning the entire length of the bioretention facility and the results were averaged as presented above. This facility had the most variable infiltration rate throughout the bioretention facility because the native soils were amended with the filter media. Overall, the bioretention facility ***passes*** the infiltration testing protocol. The results provided above are the in-situ saturated hydraulic conductivity measurements which equal the infiltration rate. The sorptivity is influenced by the initial and final moisture contents. As the moisture content approaches saturation, sorptivity tends to zero and the infiltration rate equals to the field saturated hydraulic conductivity[xx].

Recommendation: The Guelph Permeameter is a simple and fast method for performing infiltration tests, however, it is intended for native soils and any inaccuracies for use in bioretention soils are currently unknown. It is recommended to duplicate the infiltration results with other test methods such as the Double Ring Infiltrometer for higher accuracy.

Table 7. Testing Protocol: Continuous Water Level Monitoring LEVEL 3			
Assessment Item	**Metric / Passing Threshold**	**Result**	**Pass / Fail**
1 – Surface Drawdown Time (hrs)	24 hrs	-	-
2. Subsurface Drawdown Time (hrs)	48 hrs	Ranges from 18 hrs to 116 hrs	Fail
Comments: The as-constructed bioretention facility ***fails*** the water level monitoring test as the subsurface drawdown time is far more than 48 hours. The water level analysis was performed on rain events greater than 10 mm and the assessment of surface ponding drawdown rates and times was neglected due to inadequate data. Only above and below drain drawdown rates and times were calculated based on this data. As a lesson learned, additional information is needed to perform a complete analysis including surface ponding capacity and duration as recommended below. **Recommendation: In addition to the subsurface observational well, a second observational well should be added to the surface to monitor surface ponding and duration to make certain that the as-constructed facility meets the 24 hours design criteria.**			

Discussion

All testing protocols were completed by November 2013. Unitarian Congregation Church ***passes*** most testing protocols except for the soil testing, as-built survey testing and water level protocols. The key assessment items identified in these individual protocols are discussed below:

- *Visual Inspection* – During the last visual inspection, it was noted that the catchbasin is covered with a geotextile fabric which may obstruct overflow causing the facility to pond for a longer period of time. The fabric should be removed and adding a layer of rock around the catchbasin is recommended to trap the debris and keep the overflow grate free of obstruction.
- *Soil Testing* – The soil mixture does not meet the optimum texture composition for Coarse sand and silt/clay particles without having to replace the entire soil matter. This may not be necessary for the site as the bioretention mix was amended with native soils which were silty clay. There is a low organic content which can be compensated for with the addition of organic matter such as leaf matter or grass clippings into the top layer of the soil to ensure adequate nutrient supply for plant survival.
- *As-built Survey* – The surface storage volume and the subsequent total storage capacity of the facility has been reduced due to an increased contributing drainage area and reduced bioretention area. This indicates that the facility is undersized as compared to the original design.

To perform a true assessment of the facility, a visual inspection alone is not adequate. The subsurface issues which are overlooked during a visual inspection including soil mixture, organic matter and as-constructed design practices can only be determined with these additional inspections and tests.

Definitions

Best management practice(s) – are techniques that can be implemented on land to minimize the negative impacts or urbanization.

Bioretention - a stormwater filtration and infiltration practice. The practice is a shallow excavated surface depression containing a prepared soil mix, mulch, and planted with specially selected vegetation. The system is engineered to temporarily store runoff in the depression and gradually filters it through the mulch, engineered soil mix, and root zone. They remove pollutants from runoff through filtration in the soil and uptake by plant roots and can help to reduce runoff volume through evapotranspiration and infiltration.

Bulk density - the ratio of the mass of dry solids to the bulk volume of the soil

Cationic exchange capacity - is the maximum quantity of total cations that a soil is capable of holding at any given pH value and the capacity of available cations for exchange with the soil solution.

Contributing drainage area – An area that drains runoff to a specific point or practice

Deep well – a well that starts at the surface of the practice and goes to the bottom of the practice to measure moisture level within the soil.

Drawdown time – is the period between the maximum water level and the minimum level (dry-weather or antecedent level).

Ecological Land Classification - provides tools and techniques for consistent description, identification, classification and mapping of community types. The ELC is now becoming a standard method across Ontario to meet the needs of ecosystem management and landuse planning. It helps identify changes in land use.

Environmental Monitoring Assessment Network - is a branch of Environment Canada, and is a nation-wide monitoring initiative that has created a set of standardized monitoring protocols and collects data associated with the protocols to provide comprehensive and comparable monitoring across similar eco-regions within Canada (EMAN, 2009)

First flush – is the initial pulse of stormwater runoff which picks up the pollutants that have settled on surfaces during the dry period. The first flush contains the highest pollutant concentrations.

Flow-weighted – sampling frequency that involves collection of samples after a constant incremental volume of discharge that passes the AutoSampler during a rain event.

Grain size – also known as particle size refers to the diameter of individual sediment grains.

Hydraulic conductivity – is a parameter that describes the capability of a medium to transmit water.

Infiltration - penetration of water through the ground surface.

Green Infrastructure - natural vegetation and vegetative technologies in urban settings such as: urban forests; green roofs; green walls; green spaces; rain gardens; bioswales; community gardens; natural and engineered wetlands and stormwater management ponds; and porous pavement systems. These systems are designed to provide multiple benefits, such as moderate temperatures, clean air and water, and improve aesthetics.

Low impact development - a stormwater management strategy that seeks to mitigate the impacts of increased urban runoff and stormwater pollution by managing it as close to its source as possible. It comprises a set of site design approaches and small scale stormwater management practices that promote the use of natural systems for infiltration and evapotranspiration, and rainwater harvesting.

Overflows – are raised catch basins or field inlets that allow runoff surplus to continue on to the municipal sewer system during extreme rain events.

Piezometer – is an open well or a standpipe installed in the ground of an LID practice to record continuous water levels to define the water table and drawdown times.

Ponding – the ability of runoff to pool and stand within a practice, which is usually a result of water inflow rate being greater than the infiltration rate.

Post-construction – refers to after construction state

Pre-treatment - initial capturing and removal of unwanted contaminants, such as debris, sediment, leaves and pollutants, from stormwater before reaching a best management practice; Examples include, settling forebays, vegetated filter strips and gravel diaphragms.
Shallow well – is an observation well that sticks out of the surface of a BMP/LID practice to evaluate surface ponding capacity.

Subsurface - refers to the depth between the ground surface and bottom of the practice or drain.

Treatment train approach – is a combination of lot level, conveyance, and end-of-pipe stormwater management practices.

Underdrain - a perforated pipe used to assist the draining of soils.

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[i] Drake J., Y. Guo. 2008. Maintenance of Wet Stormwater Ponds in Ontario. Canadian Water Resources Journal, 33(4): 351-368.
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