Lakeview

Low Impact Development Infrastructure Performance and Risk Assessment

May 2016

Technical Report

Road Right-of-Way Retrofit

CREDIT VALLEY CONSERVATION

LAKEVIEW DRIVE, CITY OF MISSISSAUGA

LOW IMPACT DEVELOPMENT INFRASTRUCTURE PERFORMANCE AND RISK ASSESSMENT

DRAFT TECHNICAL REPORT

MONITORING RESULTS (2012 – 2015)

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LIST OF ACRONYMS AND ABBREVIATIONS

ASCE	American Society of Civil Engineers
ASTM	American Society for Testing and Materials
BMP	Best Management Practice
BMPDB	International Stormwater Best Management Practices Database
Cl^-	Chloride
Cm	Centimetre
CCME	Canadian Council of Ministers of the Environment
Cd	Cadmium
Cu	Copper
CVC	Credit Valley Conservation
EC	Environment Canada
EMC	Event Mean Concentration
Fe	Iron
G	Gram
Hr	Hour
HSG	Hydrologic Soil Group
kg	Kilogram
L	Litre
L/s	Litres per Second
LID	Low Impact Development
M	Metre
m^2	Square Metre
m^3	Cubic Metre
MDL	Method Detection Limit
mg	Milligram

µg/L	Micrograms per Litre
min	Minute
mm	Millimetre
MOI	Ministry of Infrastructure
MTO	Ministry of Transportation of Ontario
N	Nitrogen
Ni	Nickel
NSQD	National Stormwater Quality Database
NO_2	Nitrite
NO_3	Nitrate
MOE	Ontario Ministry of the Environment
PO_4	Orthophosphate
P	Phosphorus
PAH	Polycyclic aromatic hydrocarbon
Pb	Lead
PSD	Particle Size Distribution
PVC	Polyvinyl Chloride
PWQO	Provincial Water Quality Objective
RL	Reporting Limit
S	Second
SWM	Stormwater Management
SWMM	Stormwater Management Model (EPA SWMM)
TDS	Total Dissolved Solids
TKN	Total Kjeldahl Nitrogen
TN	Total Nitrogen
TP	Total Phosphorus

TSS	Total Suspended Solids
UNHSC	University of New Hampshire Stormwater Center
USEPA	United States Environmental Protection Agency
WWE	Wright Water Engineers, Inc.
Yr	Year
Zn	Zinc

EXECUTIVE SUMMARY

Stormwater management has been headline news given the flooding in Alberta and the Greater Toronto Area (GTA) in recent years. The 2016 Canadian Infrastructure Report Card documented 671 occurrences that resulted in flood damages since 2009. More than 66 000 private properties were affected, with more than $500 million in damages. The replacement value for stormwater infrastructure in very poor, poor or fair condition was estimated at $31 billion (Canadian Infrastructure Report Card 2016). This estimate does not take into consideration the need for infrastructure within existing urban areas that do not currently have systems for flood control or stormwater treatment. For example, it is estimated that only 35 percent of the GTA has stormwater management controls (TRCA, 2013). In addition to flood control, stormwater management is needed to protect streams from erosion and water quality deterioration.

Streets, sidewalks and driveways contribute 65-75 per cent of suspended solids, phosphorus and metals (Bannerman, et. al., 1992). Streets provide the greatest opportunity to control runoff as they are the largest urban contributor and are municipally owned. Low impact development (LID) retrofits that are part of road reconstruction projects have been found to save on average 25 per cent compared to traditional practices when land costs are considered (USEPA, 2007). Visit www.bealeader.ca for more information on CVC's LID sites and the Showcasing Water Innovation Project.

In an attempt to mitigate risk, the Ministry of the Environment and Climate Change (MOECC), the City of Mississauga and Credit Valley Conservation (CVC) have partnered with 18 public and private-sector organizations to implement a number of innovative stormwater management retrofits on both public and private properties. The Lakeview Green Street, situated in the south-east part of Mississauga, is the first of its kind of low impact development (LID) residential road retrofit project in Ontario.

Low Impact Development, also referred to as green infrastructure, is an integrated approach to stormwater management that utilizes small engineered controls to capture runoff as close as possible to where it is generated. Permeable pavement, bioretention filters, green roofs and cisterns are examples of the types of controls used to capture, detain and filter runoff; infiltrate and evapotranspire runoff, or store runoff for beneficial use. The primary benefits of green infrastructure techniques are water quality and stream protection. However, they also contribute to flood loss avoidance (Atkins, 2015). They can be implemented in infill, redevelopment, and retrofit projects where space is limited.

The Lakeview Green Street retrofit replaced traditional grass swales with bioswales and permeable pavement on driveways within the municipal right-of-way as an alternative to upgrading to curb and gutters with inlets and storm sewers. The LID retrofit stores and slows runoff down, and provides the opportunity for filtration and retention of stormwater through infiltration and evapotranspiration. This reduces the amount and improves the quality of stormwater flowing into storm sewers, Cooksville Creek, and eventually Lake Ontario.

The Lakeview Green Street retrofit was completed in August 2012. CVC is conducting comprehensive performance and risk assessment at this site. Monitoring of the quantity and quality of outflow from the treatment system began in September 2012. Monitoring of a traditional grass swale provided data for comparison. This report summarizes the results of monitoring from 2012 to 2015.

For seven large events, with return periods of 2 years to more than 10 years, peak flow reductions ranging from 74 to 100 per cent were achieved by the green street. The runoff volume reduction achieved by the green street for events larger than 30 mm was 72.6 per cent, compared to only 45% by the conventional grass swales. These findings support the ability of LID systems to provide resilience. The peak flow reduction achieved by the detention storage of these systems can help to reduce the frequency of surcharging in the downstream storm sewer.

For the events with magnitudes larger than 33 mm, at least 30 mm were retained (i.e. did not appear as measured outflow). The smallest event to produce outflow was a 20 mm event on April 19, 2015 when conditions preceding the storm were wet. This behavior was distinct from the conventional grass swale, which produced outflow for many events smaller than 10 mm and some events smaller than 5 mm. Retaining runoff on-site ensures that it will not contribute to downstream erosion.

Events up to 25 mm in magnitude occur much more frequently and contribute a large proportion of the average annual precipitation. Events in this size range are also responsible for transporting a large proportion of the annual contaminant mass delivered to receiving waters. Therefore, their management is particularly important for water balance and water quality objectives. The green street virtually eliminated outflow for events up to 25 mm in magnitude. The overall runoff volume reduction (for all events) achieved by the green street was 92 per cent, compared to only 68 per cent by the conventional grass swales. The green street retrofit achieved 93 per cent mass reduction of total suspended solids (TSS), exceeding the water quality criteria of 80 per cent TSS removal. The traditional grass swales also reduced the outflow mass of TSS but the 72 per cent mass reduction measured falls short of the requirement for enhanced protection of receiving waters.

The green street also had good performance with respect to mass reduction of total phosphorous (83 per cent) and metals except nickel (>90 per cent). This provides evidence of the value of low impact development retrofits for areas where these parameters are of particular concern. The mass removal of dissolved nutrients was slightly lower, with percent mass removal of ortho-phosphate and nitrate estimated at 70 and 68 per cent, respectively, for the green street. The green street out-performed the conventional grass swales, which had percent mass removals of 60 and 4 per cent for these same two constituents. The median effluent concentrations of nutrients for events which did produce outflow were higher than the conventional grass swale and curb and gutter control sites. The effluent quality was better, or similar to, other bioretention sites included in the International Stormwater Management Practices Database.

Inspections have been carried out to visually document performance and identify maintenance needs. Problems with the elevations of curb cuts were observed following construction. Removal of accumulated debris at inlets was identified as an important maintenance need. The ultimate goal is to continue monitoring long-term performance and maintenance needs for life-cycle cost assessment and asset management.

By continually monitoring at Lakeview it has been determined that the elevations of the curb cuts and grass filter strip has become an ongoing issue. Although modifications were made and some excess soil and sod were removed to lower the elevation to aid with the inflow of water, by-pass of stormwater runoff has still been an issue. Ongoing monitoring was crucial in identifying this issue and observing that the repairs were not sufficient. CVC has been working with the City to resolve this issue and property owners have also been receptive, trying to ensure their inlets are free of debris to aid in stormwater flow.

This performance data suggests that widespread adoption of LID would yield significant benefits to receiving streams as well as the Great Lakes. Results from the Lakeview Green Street retrofit, and other similar performance studies, will provide municipalities with the knowledge they need to make informed decisions on the role of green infrastructure for stormwater management. They are essential to gain insights into preferred designs and advancements which may be needed to meet stormwater management and other objectives cost-effectively.

1 BACKGROUND

1.1 The State of Stormwater Infrastructure in Ontario

Canada's aging infrastructure is receiving a great deal of attention due, in part, to the frequency of flood events such as the 2013 floods in southern Alberta and Greater Toronto Area (GTA). The 2016 Canadian Infrastructure Report Card documented 671 occurrences that resulted in flood damages since 2009. More than 66 000 private properties were affected, with more than $500 million in damages. The replacement value for stormwater infrastructure in very poor, poor or fair condition was estimated at $31 billion (Canadian Infrastructure Report Card 2016). This estimate does not take into consideration the need for infrastructure within existing urban areas that do not currently have systems for flood control or stormwater treatment. For example, it is estimated that only 35 percent of the GTA has stormwater management controls (TRCA, 2013). To bring older developments across the nation to today's standards, Federation of Canadian Municipalities (FCM) estimated it would cost an additional $56.6 billion (FCM, 2007). This figure assumes conventional practices are feasible and does not include land acquisition costs, which, in growth areas around Toronto, can be three or four times that of infrastructure costs (Reinthaler, Partner, Schaeffers & Associates Limited, 2012). Building cost-effective resiliency into stormwater infrastructure requires an alternate solution.

The estimated damage of the July 8, 2013 storm event is almost $1 billion, and is now the most expensive storm in Ontario's history (IBC, 2014) Both nationally and locally, water damage is the largest single component of insured loss with claims tallying $1.7 billion per year (IBC, 2012).

In the United States, Europe and Australia there has been a growing movement towards green infrastructure for stormwater management over the last 20 years. Green infrastructure for stormwater management, also referred to as low impact development (LID), is an integrated approach to stormwater management that uses site planning and small engineered controls to capture runoff as close as possible to where it is generated. LID controls can be incorporated within urban environments where space is a constraint. They can be implemented in infill, redevelopment and greenfield sites to meet stormwater management objectives.

Flood control is not the primary purpose of low impact development, but LID has the ability to reduce runoff volumes and delay runoff thereby reducing pressures on downstream stormwater infrastructure and receiving waters. A recent report generated estimates of the monetary value of flood loss avoidance that could be achieved by green infrastructure implemented watershed-wide, in new development and redevelopment, in the United States (Atkins, 2015). The present value of flood losses avoided between 2020 and 2040 for the conterminous United States, assuming no damages within the 10 year floodplain and a 3% discount rate, was estimated at $0.8 billion dollars (Atkins, 2015). If green infrastructure were used to retrofit existing imperviousness, the flood loss avoidance benefits would be even higher.

The primary benefits of green infrastructure are water quality and stream protection. Practices such as permeable pavements and bioretention systems can retain the water from events that occur relatively often. This helps to mimic pre-development hydrological conditions and reduce stream erosion. Stream erosion is a common response to high flows that occur more often and for longer durations after urbanization. Most of the pollutants that accumulate in urban areas are carried to streams and other receiving waters by the moderate sized events that occur more frequently. Therefore, capturing and treating the runoff from these events can play a large role in protecting water quality.

Bannerman et al. (1992) found that streets, sidewalks and driveways can contribute a large amount of urban runoff and pollutants; with streets contributing up to 65-75 per cent of the TSS, total phosphorus (TP), copper (Cu) and zinc (Zn). Given that streets are the largest urban contributor and are municipally owned land, they provide the greatest opportunity to mitigate stormwater runoff.

1.2 The Need for Long Term Performance Assessment of LID Techniques in Ontario

The MOECC (through Sustainability Planning) requires Ontario municipalities to develop asset management plans when requesting provincial infrastructure funding. Asset management is an integrated life-cycle approach to effective stewardship of infrastructure assets to maximize benefits, manage risk, and provide satisfactory levels of service to the public in a sustainable and environmentally responsible manner.

One of the barriers to widespread adoption of LID in Ontario is the limited local, long-term performance data available to conduct the integrated life-cycle analysis required for asset management. The lack of data for practices, individually and in combination, makes it difficult for designers to select and size stormwater infrastructure, for municipalities and landowners to budget for maintenance costs and for approval agencies to permit these innovative techniques in varied land-use applications.

To build confidence in sizing and long-term performance of stormwater infrastructure, CVC and its partners have implemented a series of demonstration sites within various land-use settings and are delivering a LID Infrastructure Performance and Risk Assessment (IPRA) program. The multi-year IPRA program will evaluate LID effectiveness in flood control, erosion protection, nutrient removal, and mimicking the pre-development water balance. This program will produce performance data addressing the outstanding knowledge gaps and priority stakeholder objectives identified by multiple stakeholders within CVC's Stormwater Management Monitoring Strategy (2012). Section 2 of this report discusses the 19 objectives identified for CVC's overall stormwater management monitoring program.

LID performance data inherently supports Ontario's Water Opportunities Act, the Great Lakes Protection Act, and recommendations from MOECC's Policy Review of Municipal Stormwater Management in the Light of Climate Change by providing information on innovative water technologies. Building on the findings of existing research, CVC's program will also advance the understanding of maintenance requirements for optimal LID performance and life-cycle cost analysis for asset management to meet provincial requirements for sustainability planning.

The knowledge gained through performance evaluation will strengthen existing tools and be used to create new tools to support longer scale implementation. This research directly supports the protection of the Great Lakes by providing elected officials, municipal engineering and operations personnel, developers, contractors, consultants and businesses and residential landowners with the tools they need to successfully implement LID in their communities.

1.3 Lakeview District – Green Infrastructure Design

The City of Mississauga partnered with CVC to develop a Green Street project for the Lakeview District in the Cooksville Creek watershed with funding from anMOECC Showcasing Water Innovation grant. This location is one of a few areas in the City of Mississauga using vegetated swales as opposed to a curb and gutter system for drainage. The City chose to incorporate LID practices in the retrofit rather than upgrade to a curb and gutter system. For the City and community, this would mean:

- Improving the overall aesthetic appearance of the area with plantings
- Minimizing the ditch profile for improved maintenance
- Improving water conveyance and eliminating standing water in the ditches

This project provided an ideal opportunity to demonstrate the effectiveness and community acceptance of green street designs. The City of Mississauga installed bioswales along the residential streets and permeable pavement at the end of residential driveways. These features can help manage stormwater runoff by slowing it down, filtering it and providing storage and the opportunity for infiltration. This reduces the amount and improved the quality of stormwater flowing into storm sewers and eventually Lake Ontario. **Figure 1-1** shows the location of the Lakeview site within the Cooksville Creek watershed.

Flooding in the Cooksville Creek watershed over the past 10 years has led to the adoption of a number of large stormwater infrastructure projects to aid in flood mitigation. Projects include a large berm to reduce ravine flooding and upgrading the watercourse and crossing capacity. These large infrastructure projects take many years for plan, design and implement and they require land and multi-million dollar budgets. LID stormwater retrofits, like Lakeview, are smaller scale projects and can be designed and implemented more quickly, with smaller budgets and alleviate the pressure on overburdened stormwater management infrastructure.

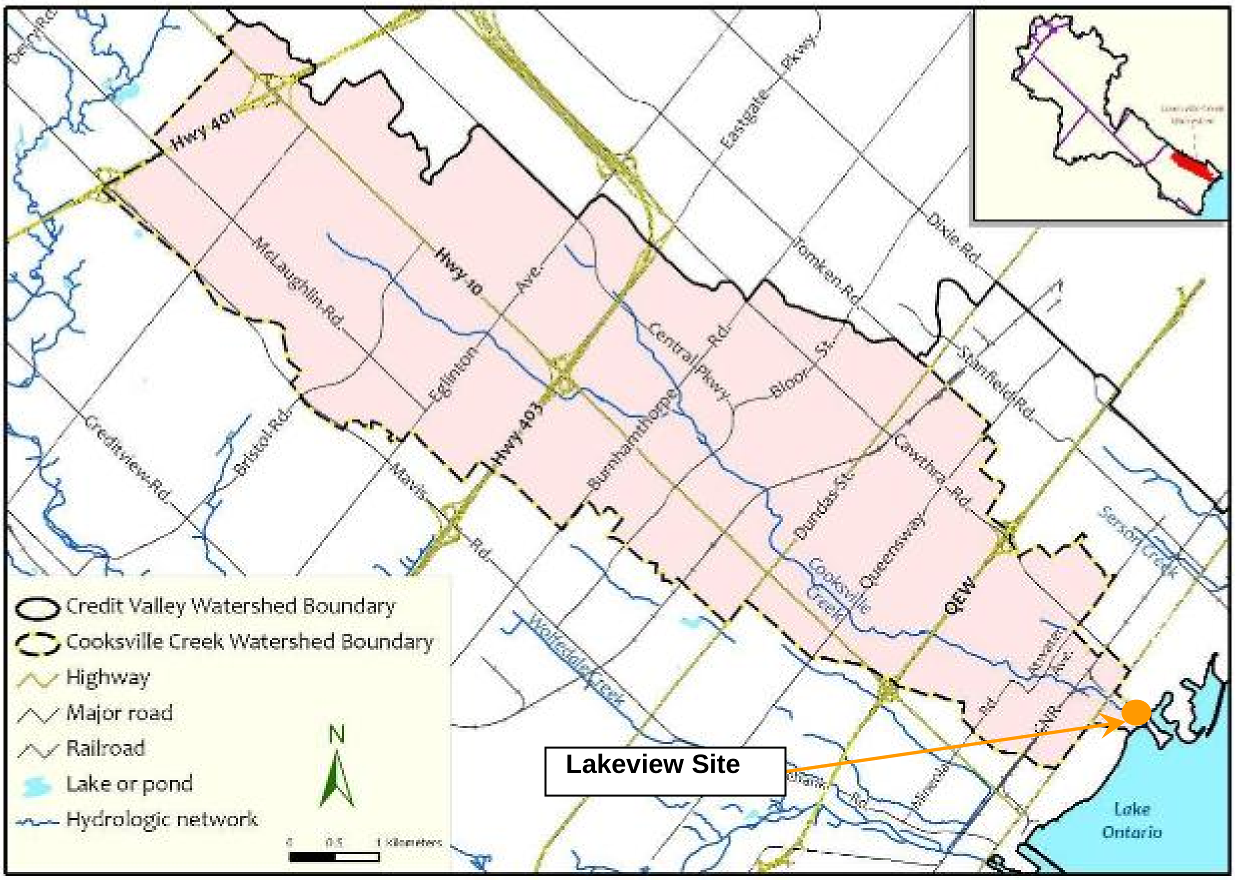


Figure 1-1: Lakeview study area within the Cooksville Creek watershed

1.4 Community Involvement

The Lakeview neighborhood was actively involved in the right-of-way project (**Figure 1-2**, **Figure 1-3**). Communications with the residents was initiated early in the project through door to door conversations and newsletters. A series of public events were held in the community with artistic renderings, colourful design drawings, street views, bioswale cross-sections, photos from other projects, and samples of permeable paving stones. Multiple alternative plans were presented to the public and questionnaires were provided to assess residents' reactions to alternatives and measure the level of acceptance. Community input guided the detailed design, including identifying traffic safety issues with poor lines of sight on a local street. The most important issues for the residents in the Lakeview neighbourhood included:

- Parking
- Stormwater quality
- Urban impacts on the environment
- Residential flooding
- Lack of integration with the Lakeview neighbourhood

The Lakeview project provided opportunities for landowners to gain stormwater education and to understand their responsibilities in stormwater management. Residents were given the opportunity to choose how the bioswale on their property would be landscaped, with either grass or perennial plants. If residents chose the plant option, they were able to select the plants to be used, furthering their participation. Two-thirds of the residents were willing to participate in two to four hours of maintenance activities each month, encouraging the City to move forward with the project. CVC provides the residents guidance on maintenance activities and frequency for all seasons, and planting advice if requested.

Community events were held to inform residents on the best way to maintain their bioswales for both optimal performance and aesthetics. Upon project completion there was an event where residents were able to interact with the different designers who were involved in the project, including the engineers who designed it and the landscapers who created the planting plans. Residents were able to get additional information about the street as a whole and had the opportunity to have individual consultations on their properties. This allowed them to have specific questions answered and receive guidance to both enhance and maintain their bioswales

Figure 1-2: Lakeview residents attending a community information session about the LID retrofit project planned for their street prior to construction

Figure 1-3: A Lakeview resident receiving a private consultation from a Landscaper at the "Ask a Designer" night event

2 LID MONITORING OBJECTIVES

To build consensus and overcome barriers to wide scale adoption of LID, CVC worked with project partners and stakeholders (**Figure 2-1**) to define 19 objectives to direct CVC's stormwater management monitoring program. CVC held several meetings to collect input from stakeholders including municipal decision makers, provincial and federal environmental agencies, engineering and planning professionals, conservation authorities, academia, and watershed advocacy groups.

Figure 2-1: Stormwater professionals meeting to discuss LID

The stakeholder group identified the following program objectives (the objectives in bold are applicable to Lakeview):

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

16. **Assess the ancillary benefits, or non-stormwater management benefits.**
17. Assess the potential for groundwater mounding in localized areas.
18. **Improve and refine the designs for individual LID practices.**
19. **Assess the overall performance of LID technologies under winter conditions.**

3 SITE DESIGN

The City of Mississauga and CVC partnered to develop a “Green Street” pilot project for two streets in the Lakeview District Neighbourhood located in southeast Mississauga. This area of Mississauga is one of the few areas that still had vegetated swales for drainage as opposed to curb and gutter. As an alternative to upgrading the traditional grass swales to curb and gutter with inlets and storm sewers, a design using bioswales and permeable pavement on driveways within the municipal right-of-way was developed. **Figure 3-1** illustrates the green street retrofit design.

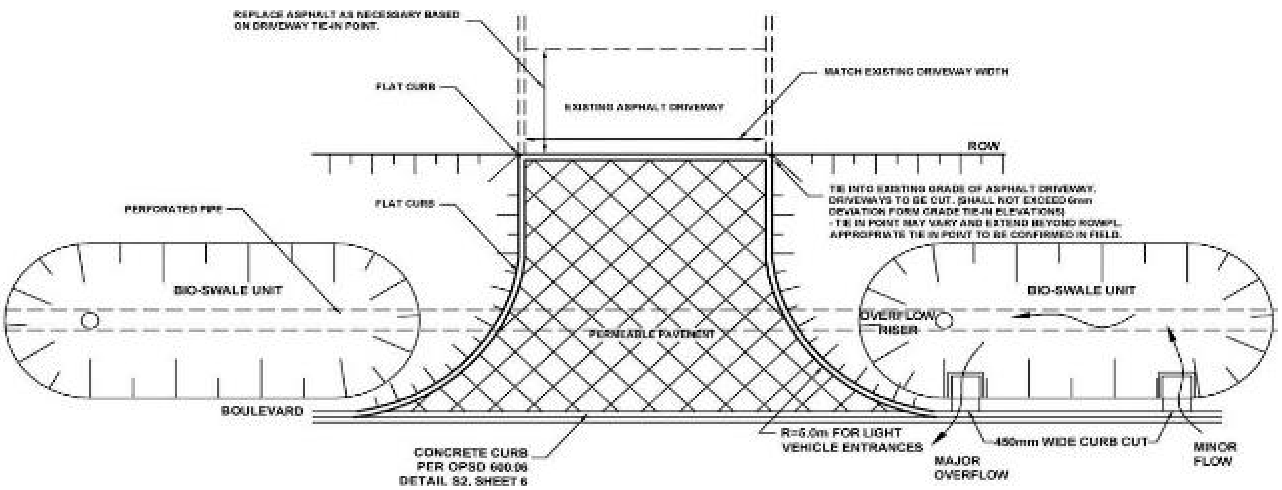


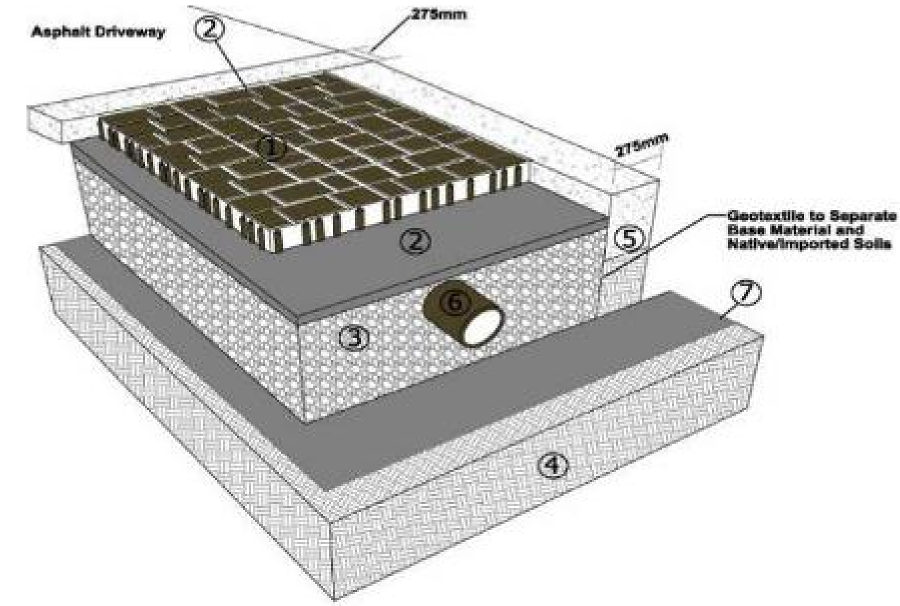
Figure 3-1 Typical configuration and layout of LID practices implemented within the residential right of ways.

3.1 Low Impact Develop Systems

3.1.1 Permeable Pavement

Permeable pavement allows for storage and infiltration of stormwater, which can reduce stormwater volume and flowrates compared to traditional impervious paving surfaces like concrete and asphalt. It also provides filtration and other treatment processes to improve stormwater quality relative to that from traditional pavements. A cross-section, showing the components of the permeable pavement system is provided in **Figure 3-2**.

The surface layer consists of paving stones with spacers deliberately creating gaps between stones. Chip stone is used as a bedding layer for the pavers and to fill the gaps between stones. The chip stone filled gaps readily allow water on the surface to infiltrate into the base layer which provides subsurface storage. Stormwater that enters the subsurface storage layer has the opportunity to infiltrate into the native materials. If the storage fills to the elevation of the underdrain pipe, excess water is conveyed downstream via the outlet. The non-woven geotextile is placed directly on the prepared subgrade and up the sides of the excavated trench to prevent the migration of fines from the native subsoils into the aggregate base. **Figure 3-3** shows the installation of the subsurface and surface components of the permeable pavement.



(1) Permeable Pavers

(2) Chip stone

(3) Clearstone base

(4) Subgrade

(5) Excavated trench

(6) Outlet

(7) Non-woven geotextile

Figure 3-2 Permeable pavement driveway cross-section

Figure 3-3 Preparation of permeable pavement driveway base materials (left) and permeable pavers (right)

Permeable pavement was installed on the lower portion of residential driveways, within the City owned right of way. The original pavement was maintained in the resident owned, upper portion, of the driveways.

3.1.2 Boulevard Bioswale Units

Bioswale units are soil filter systems that temporarily store and filter runoff. These units rely on the engineered soil media placed below the channel invert to provide stormwater runoff reductions and improve water quality. Street runoff flows along the curb and enters the bioswale through curb cuts (**Figure 3-4**) placed in front of each swale.

Figure 3-4 Curb cuts allow road runoff to enter the vegetated bioswales

On the surface, bioswales may appear as simple grass channels or may have more elaborate landscaping. Bioswales can be planted with sod, tall meadow grasses, decorative herbaceous cover, or trees. The planted vegetation is used to improve the visual aesthetics of the swale, to provide some pretreatment (filtering out larger particles), and to protect the filter media from erosion. The vegetation itself may not play a significant role in removing contaminants but may be important for providing habitat for microorganisms that can play a substantial role in contaminant degradation and transformation. Mulch is placed around the vegetation, to maintain soil moisture and inhibit the growth of unwanted weeds. Half of the residents in the Lakeview neighbourhood chose to have a vegetated bioswale with perennial plants, while the other half chose grass.

Stormwater runoff treated by the soil media bed flows into the ground or the underdrain (**Figure 3-5**), which moves treated runoff to the subsurface stormwater conveyance system further downstream. The underdrain consists of a perforated pipe within a gravel layer below the engineered media bed. The non-woven geotextile cloth fully wraps the gravel so it covers the top of the gravel, separating the gravel and soil materials.

Figure 3-5 Bioswale with underdrain in gravel layer (left), Engineered soil mix within the bioswale (right)

An overflow pipe with a debris screen (**Figure 3-6**) is connected to the underdrain. The pipe allows stormwater to flow directly into the underdrain if ponded water becomes too deep.

Figure 3-6 Overflow pipe with debris screen (left), Soil media being installed around an overflow pipe (right)

3.2 Design Information

Table 3-1 summarizes key sizing and design information. The bioswale design is illustrated in **Figure 3-7**.

Table 3-1: General dimensions of the boulevard bioswales

System component	Value
Top width	2.5 – 3.0 m
Bottom width	2.5 m
Total excavation depth	1.5 – 2.0 m
Ponding depth above engineered soil media	90-150 mm
Soil media depth	450 – 600 mm
Aggregate depth above obvert of underdrain (aggregate size)	100-150 mm of No.57 clear washed stone
Underdrain	300 – 375 mm ø perforated HDPE pipe
Aggregate depth below invert of underdrain (aggregate size)	500 mm of No.57 clear washed stone (20 mm ø)

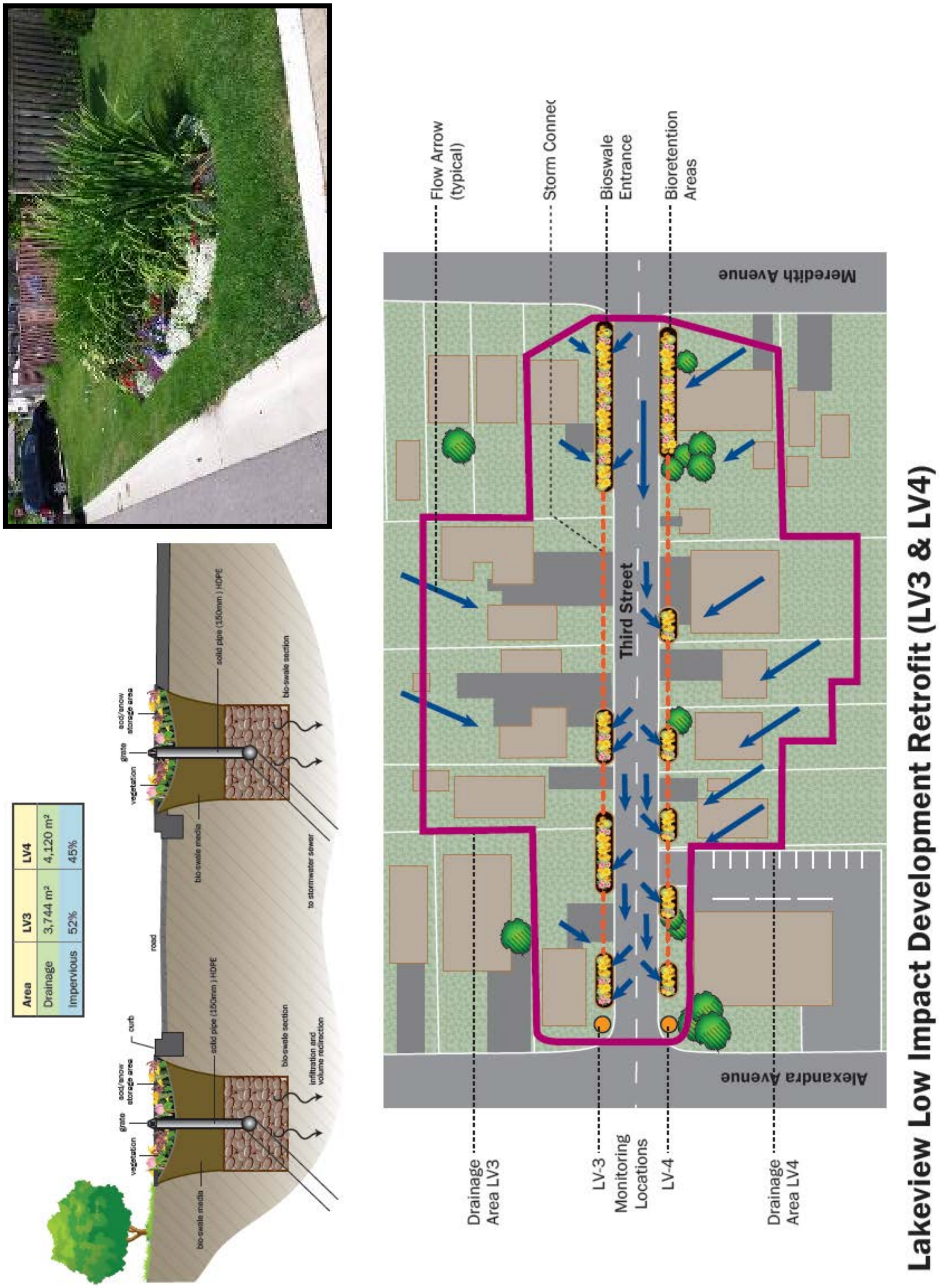


Figure 3-7 Overview of bioswale cross-sections and locations on Third Street with arrows showing direction of stormwater flow

The soil media in the bioswales is an engineered soil mixture that allows stormwater runoff to infiltrate, filters the stormwater, and serves as a growth medium for vegetation. **Table 3-2** provides the specifications for the engineered soil mix.

Table 3-2: Engineered soil media specifications

Characteristic	Requirement
Physical characteristics	Sand (2.0 to 0.05 mm Ø) - 85-88% Fines (<0.05 mm Ø)) – 8-12% Organic matter – 3-5% No objects greater than 50 mm Hydraulic conductivity greater than 25 mm/hr
Chemical characteristics	CEC greater than 10 mg/100 g pH 5.5-7.5

The size of the bioswale units was limited to the space available between the roadway and the home owner's property line. The intent of the design was to control as much stormwater as possible within the catchment. Volumetric storage calculations were used to evaluate the ability of the proposed design to provide storage for the water volume associated with a 25 mm event. Table 3-3 summarizes the storage provided by the design for the bioswales on the south side of Third Street.

Capture and treatment of up to 25 mm precipitation depth is expected to be able to meet the MOECC requirement for 80 percent Total Suspended Solids (TSS) removal for enhanced treatment. Retention of this amount of precipitation would eliminate the site's stormwater contributions to downstream stormwater infrastructure for events less than 25 mm and mitigate erosion of the receiving watercourse. The storage necessary to accomplish these objectives is also expected to reduce peak flow rates.

Table 3-3 Bioswale design storage compared to storage targets

Characteristic	LV-4 (South side of street)
Drainage area	0.412 ha
Impervious area	45%
Number of bioretention cells	5
Surface area	163 m^2
Design Storage	
Surface storage (90-150 mm depth)	14.7 -24.4 m^3
Storage below underdrain invert	8.2 m^3
Additional subsurface storage	at least 50 m^3
Storage Targets	
Water quality treatment volume target (filtration of 25mm)	103 m^3
5 mm retention volume	21 m^3
MOE SWMPD 2003 Water quality storage volume requirement per hectare	27.5 m^3/ha
MOE SWMPD 2003 Water quality storage volume requirement	11.3 m^3

3.3 LID Monitoring Design

The Lakeview project provides the opportunity to evaluate the effectiveness of the green street retrofit to reduce the volume and improve the quality of stormwater runoff from the neighbourhood roads. The information collected from the LID assessment will help improve the knowledge of LID performance in Ontario and support implementation of future LID projects.

Figure 3-8 provides an overview of the study area with all of the monitored catchments. This figure shows the close proximity of the water quality reference site (LV-1) to the swale (LV-2) and bioswale (LV-4) monitoring sites.

Figure 3-8 Overview of catchments monitored within the Lakeview neighborhood

The LV-1 catchment, which has typical curb and gutter to inlet and storm sewer pipe systems, was intended to serve as a reference and water quality control site (**Figure 3-9**). Four catch basins (shown in red) located upstream capture and convey runoff towards the sampling location referred to as LV-1. The LV-2 catchment, which has conventional vegetated swales for drainage, allows the benefits of the enhancements to be evaluated (**Figure 3-10).** The monitoring manhole, LV-2, was used for pre-construction monitoring and continues to be monitored post construction, providing baseline data for traditional ditches. **Figure 3-11** shows the locations of LV-3 and LV-4 on one of the retrofitted streets. LV-3 receives drainage from the north side of the street. Data from LV-3 are not analyzed in this report; modifications to improve the LID features are planned, such as potentially modifying the inlet curb-cuts to allow more inflow of stormwater runoff. Runoff from the south side of the retrofitted street flows to LV-4.

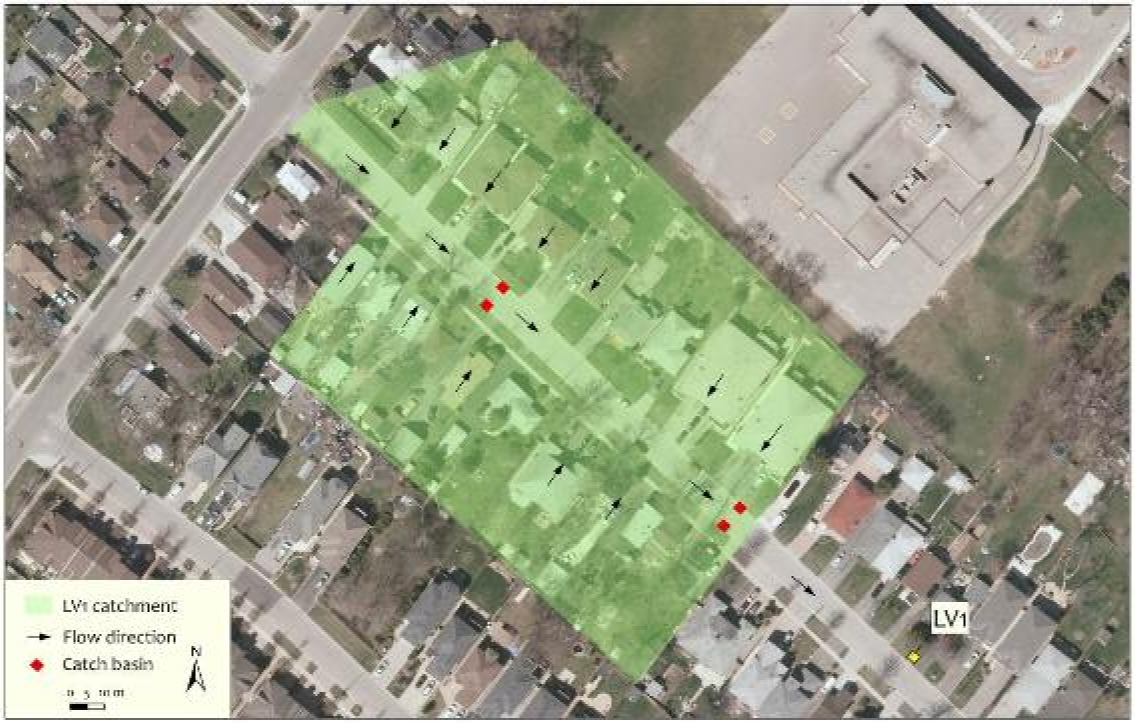


Figure 3-9 LV-1 Water quality reference site drainage area with direction of runoff

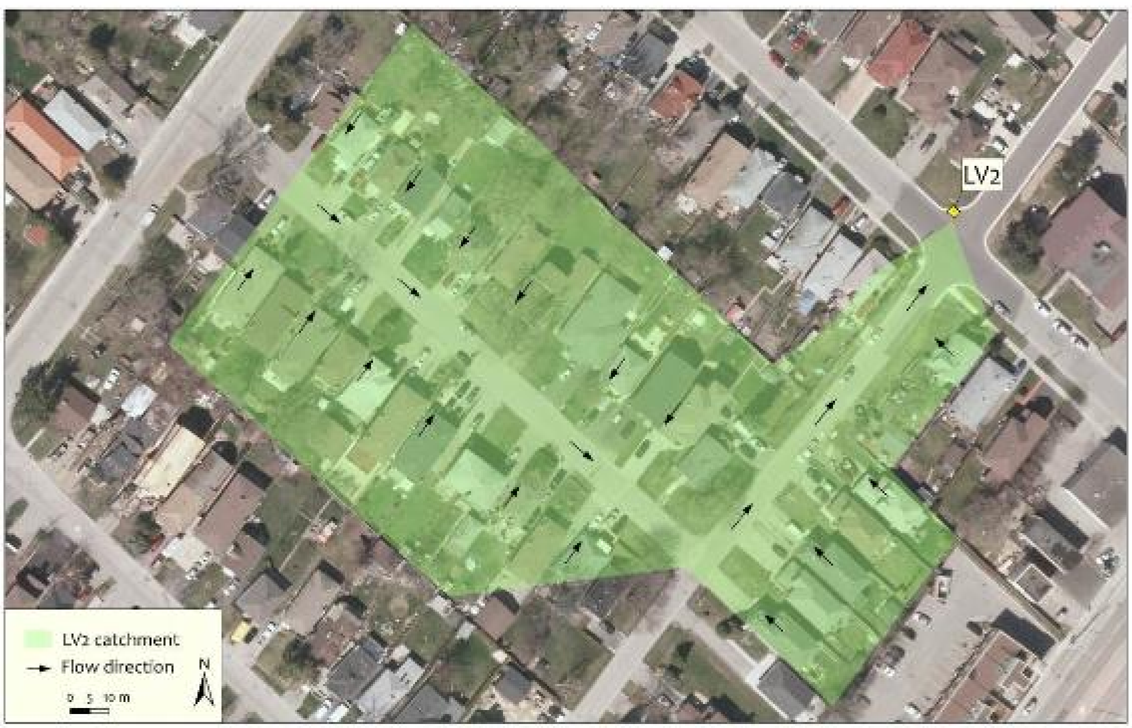


Figure 3-10 LV-2 traditional grass swale drainage area with direction of runoff

Figure 3-11 LV-3 LID retrofit collecting runoff flows from center to north side of street and LV-4 LID retrofit collecting runoff from center to south side of street.

4 MONITORING RESULTS AND INTERPRETATIONS

This section provides results from the analysis of monitoring data collected from January 2012 through June 2015. The monitoring program for the Lakeview area collects data including precipitation and flow, temperature and water quality of the outflow from control and LID sites. (**Table 4-1**) summarizes the monitoring locations and equipment within the Lakeview study area. Details on the monitoring protocols and data management and analysis methods can be found in **Appendix A**, **B and C.**

Table 4-1: A summary of the measurement type, monitoring equipment and monitoring locations

Measurement type	Monitoring equipment	Location / description
Flow	Custom Compound Weir by Thompson Flow Investigations & ISCO 4150 Flow Logger (water level meter) or HACH FL901	Downstream manhole at LV-1, LV-2, LV-3 and LV-4
Rainfall depth and intensity	Hydrological Services TB3 Tipping Bucket Rain Gauge	Roof of community fire station (approx. 850 metres from LV monitoring stations)
Water quality samples	ISCO 6712 Automatic Sampler	Manhole downstream of drainage area at LV-1, LV-2 and LV-4
Subsurface water level	HOBO U20	Observation wells within bioretention cells at LV-3 and LV-4
Temperature	HOBO UA-002-64K	Manhole downstream of drainage area at LV-1 and LV-4

4.1 Precipitation

Precipitation data is acquired from the City of Mississauga rain gauge located on the community fire station, approximately 850 metres away from the monitoring sites. The data includes the precipitation amount and how its intensity varies during an event. An Environment Canada gauge located at Toronto Pearson International Airport, with a long-term record, is used to provide an understanding of regional "normal" or average precipitation values.

Table 4-2 compares the monthly and annual precipitation measured at Toronto Pearson International Airport to the precipitation recorded at Lakeview from 2012 to June 2015. The average annual precipitation for the 30 years from 1971 to 2000 for Toronto Pearson International Airport was 793 mm. In 2012, 2013, and 2014, the annual precipitation depths at Lakeview were 707, 948, and 687 mm, respectively. In 2012 the total precipitation was 11 percent lower than the long term average at Toronto Pearson International Airport. For 2013, the Lakeview precipitation was 20 per cent higher than the annual average at Toronto Pearson International Airport, mainly due to the extreme event that occurred on July 8th. This event delivered 81.4 mm of rain in the Lakeview area, which contributed just over 8 per cent of the total precipitation for 2013. In 2014, the total precipitation was 13 per cent lower than the annual average at Toronto Pearson International Airport.

Understanding the relative contributions of events of different sizes to annual rainfall is important for interpreting performance results. **Figure 4-1** presents the number and percentage of events at Lakeview (2012 – 2015) that fell within various magnitude ranges compared to long-term averages for Toronto Pearson International Airport (1960 to 2012).

Precipitation events are defined as periods of precipitation with a depth of 2 mm or greater. The comparison suggests that the frequency of events of various sizes at Lakeview was similar to the long-term regional frequency of occurrence. The table shows that events less than 25 mm constitute about 92 percent of all precipitation events which compares well with the long-term average for the airport (90per cent); although during the study period these events contributed only 68 percent of the total precipitation. Because events up to 25 mm in magnitude occur much more frequently and contribute a large proportion of the average annual precipitation, their management is particularly important for water balance objectives. Events in this size range are also responsible for transporting a large proportion of the annual contaminant mass delivered to receiving waters. Therefore, their management is also critical to achieve water quality objectives. For flood control objectives it is the large events, which occur less frequently, that are important.

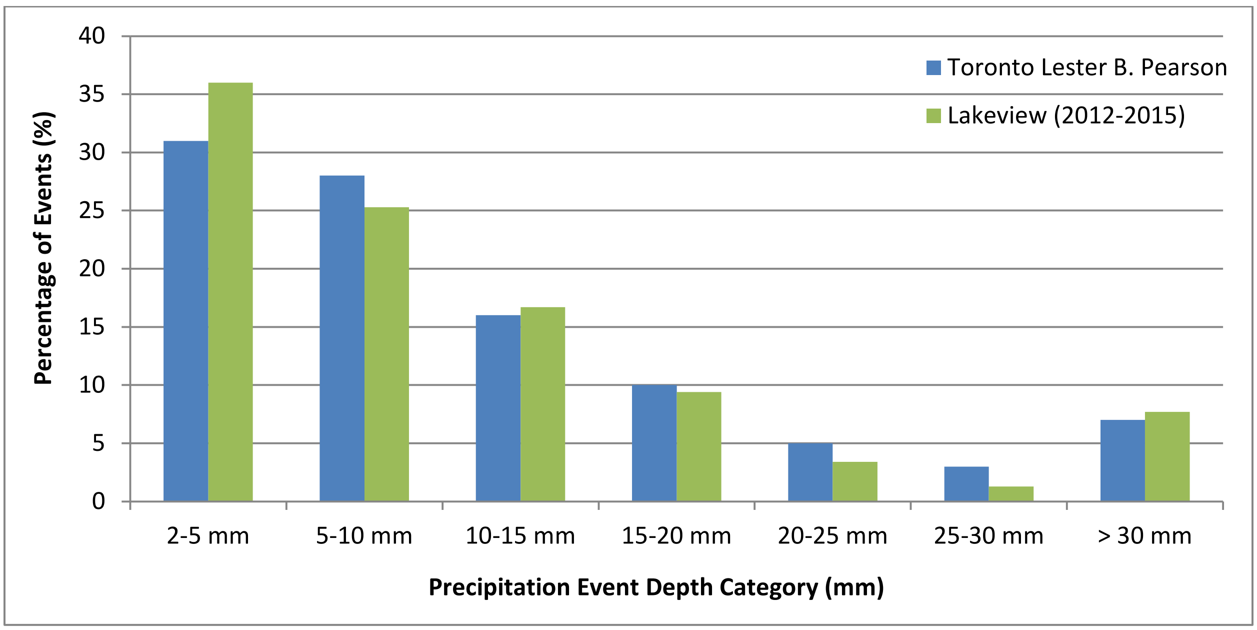


Figure 4-1 Annual number and percentage of events in different magnitude ranges

Table 4-2: Monthly precipitation summary for Lakeview compared to the 30 year average for Pearson International Airport (Source: http://climate.weather.gc.ca/index_e.html).

Toronto Pearson International Airport													
	Precipitation (mm)												
Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1971-2000	52.2	42.6	57.1	68.4	72.5	74.2	74.4	79.6	77.5	64.1	69.3	60.9	**793**
Lakeview													
2012	43.2	22	19.5	38.1	41.8	83.3	74	54.6	108.4	148	13.2	61.2	**707**
2013	81.2	84.8	24.6	115.8	75.8	90.2	160.6[1]	61.4	73.8	83.2	38.8	57.8	**948**
2014	46.4	45.8	18.8	97.0	61.8	66.8	95.8	39.4	87.8	59.0	41.6	26.6	**687**
2015	25.6	16.8	14.4	72.0	51.4	132.2	N/A	N/A	N/A	N/A	N/A	N/A	N/A

[1] Includes July 8, 2013 precipitation event of 81.4 mm in 6 hours

4.2 Hydrology

In environments with natural land cover, surface runoff is generally low and represents a small fraction of the total precipitation (Prince George's County, 1999). Water that infiltrates into the soil contributes to soil moisture and groundwater. Groundwater is often important for supplying water to streams and wetlands and maintaining their ecological integrity. Some water is returned to the atmosphere by evaporation and transpiration.

Land development converts permeable land into impermeable surfaces, including buildings, roads and parking areas. This reduces infiltration and evapotranspiration and increases surface runoff as shown in **Figure 4-2**. Natural drainage is often replaced by curbs and gutters along roadways and storm sewer pipes which rapidly deliver runoff to receiving waters. This contributes to increased peak flow rates.

Cook and Dickinson (1986) examined the impacts of urbanization, including the installation of a stormwater conveyance system near Guelph, Ontario. Compared to pre-development conditions, the researchers noted changes in the hydrologic response including: increased annual runoff volume, reduced hydrograph lag times, and increased hydrograph peak discharge.

Figure 4-3 shows the hydrologic response to two events under pre- and post-development conditions (Schueler, 1987). Urban development also alters the timing of flows and generates runoff for events which produced no runoff under pre-development conditions (Walsh et al., 2005).

The effects of increased imperviousness and rapid conveyance must be controlled through stormwater management techniques. End of pipe practices like detention ponds, can help to reduce the peak flows in receiving waters by storing the runoff and releasing it over a longer period. However, this approach does not mitigate the increase in runoff volume, which is necessary to manage hydrologic changes, erosion, and contamination of receiving waters. In contrast, low impact development practices capture and store water as close to the source as possible, and reduce runoff volume by allowing natural hydrologic processes including infiltration and evapotranspiration.

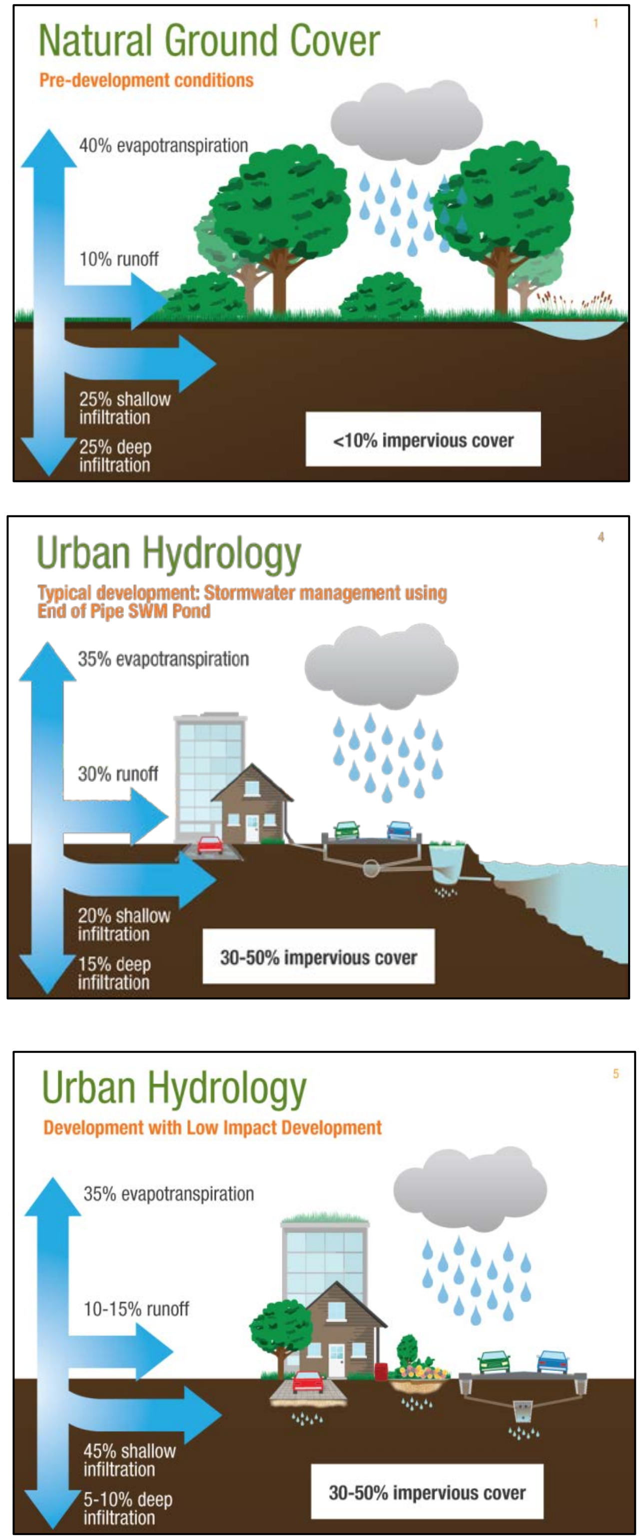


Figure 4-2 Urban water cycle with stormwater management ponds and LID (adapted from FISRWG, 1998)

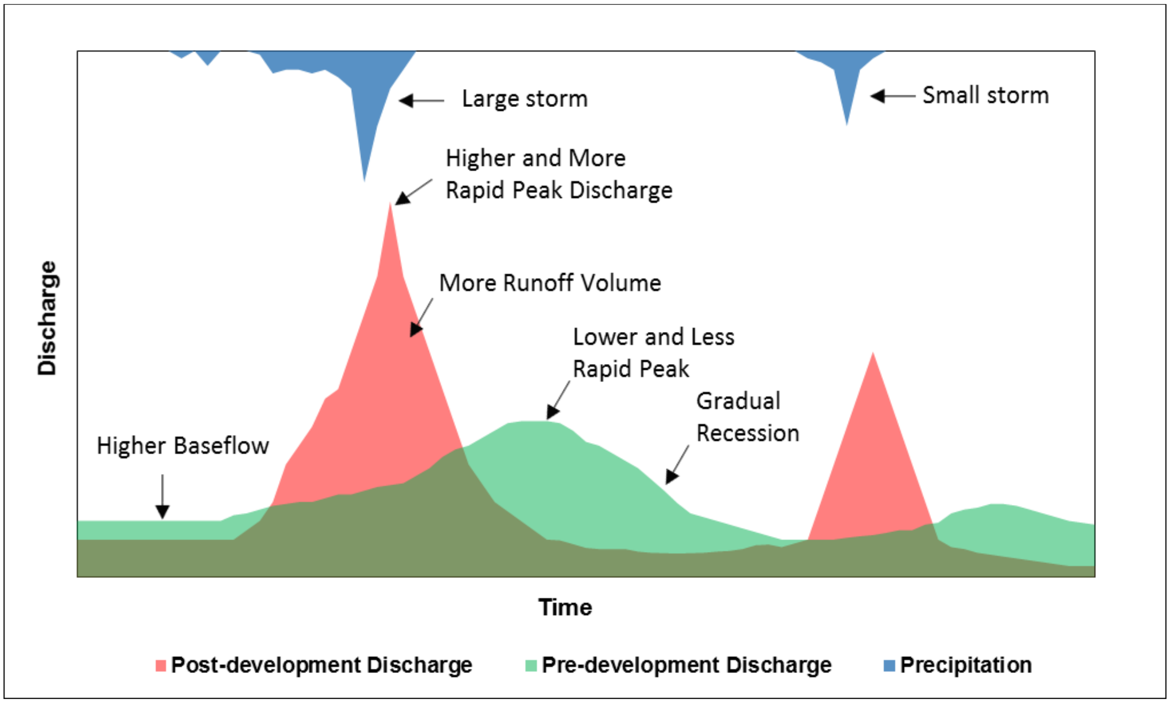


Figure 4-3 Changes in stream flow hydrograph as a result of urbanization (adapted from Schueler, 1987)

The following section presents the hydrologic performance results for the 2012-2015 monitoring period.

4.2.1 4.2.1 Overview of Analysis

Inflows were not measured at Lakeview but were estimated using the Simple Method (Schueler, 1987). The Simple Method transforms rainfall depth into flow volume based on area and impervious cover (NH DEP 2008). While this method is intended to be applied to estimate annual runoff volume, in this case it is applied to a smaller time step. There are notable caveats to application of the Simple Method that are well documented such as:

- The Simple Method uses a runoff coefficient to calculate runoff which is entirely based on the impervious cover in the subwatershed. The linear equation used to represent this relationship is a generalized equation and would be expected to have high uncertainty especially in cases where on the ground flow measurements are unavailable for validation.

- The Simple Method is most appropriate for assessing and comparing the relative stormflow pollutant load changes of different land uses and stormwater management scenarios. Because all land surfaces are defined and the land use does not change in the catchments from year to year, this is not an issue.
- The Simple Method provides estimates of storm pollutant export that are likely representative of the "true" but unknown value for a site, catchment, or subwatershed. However, it is important not to over emphasis the precision of the results obtained. We have used data from the region to “tailor” the pollutant concentrations used in this analysis but recognize that this is not the same as measuring influent concentrations. For this reason, we have termed the influent EMCs as “estimates.”

LV-2 receives inflow from a residential block as sheet flow and interflow (which is difficult to measure). LV-4 receives inflow from the south side of the LID retrofitted street as sheet flow and interflow.

LV-2 effluent flow is measured in a downstream manhole which receives runoff from a series of traditional grass-lined ditches. LV-4 effluent flow is measured in a manhole downstream of the bioswales and permeable pavement driveways. Outflow was measured continuously and reported at 10 min intervals. Runoff volume as well as time and magnitude of peak flow were observed.

The analysis includes an examination of the hydrologic response of the site for selected events. Performance under large event (>25 mm) conditions is assessed, based on peak flow reduction and "peak to peak" lag times. The emphasis of the assessment is on the estimated runoff volume reduction for events of various magnitudes.

Table 4-3 and **Table 4-4** present the hydrologic summary for events monitored at each of the stations between January 2012 and June 2015. The total number of events and the specific events monitored differed slightly between the stations due to different drainage areas and stormwater management design. The flow events are defined as having an inter-event duration of 6 hours or more.

Table 4-3: LV-2 Traditional Grass Swales Event precipitation, flow, and volume statistics: January 2012 to July 19, 2015

Statistic	Antecedent dry period (days)	Event duration (hrs)	Peak precipitation intensity (mm/hr)	Total precipitation (mm)	Normalized peak effluent flow (L/s)	Normalized influent volume (L)	Normalized effluent volume (L)	Estimated Volume Reduction (%)
Count	222	223	208	208	129	223	223	208
Mean	3.3	12.6	11.9	10.9	0.47	3.86	1.23	82.4
Median	1.6	8.0	7.2	7.2	0.16	2.58	0.05	98.6
25th %	0.7	4.1	3.6	4.0	0.05	1.37	0	78.8
75th %	3.8	14.2	13.2	13.4	0.38	4.63	0.91	100

Table 4-4 LV-4 LID Event precipitation, flow, and volume statistics: January 2012 to July 19, 2015

Statistic	Antecedent dry period (days)	Event duration (hrs)	Peak precipitation intensity (mm/hr)	Total precipitation (mm)	Normalized Peak effluent flow (L/s)	Normalized estimated influent volume (L)	Normalized effluent volume (L)	Estimated Volume Reduction (%)
Count	205	205	203	203	14	205	205	203
Mean	2.6	9.0	12.2	10.8	1.35	4.03	0.32	97.9
Median	1.7	7.0	7.2	7.0	0.14	2.65	0	100
25th %	0.7	3.3	3.6	3.8	0.07	1.44	0	100
75th %	3.8	12.0	13.2	13.6	0.28	5.14	0	100

4.2.2 Hydrologic Response to Selected Events

Hydrographs for two events that produced outflow at LV-4 in 2015 are illustrated in **Figure 4-4** and **Figure 4-5.**

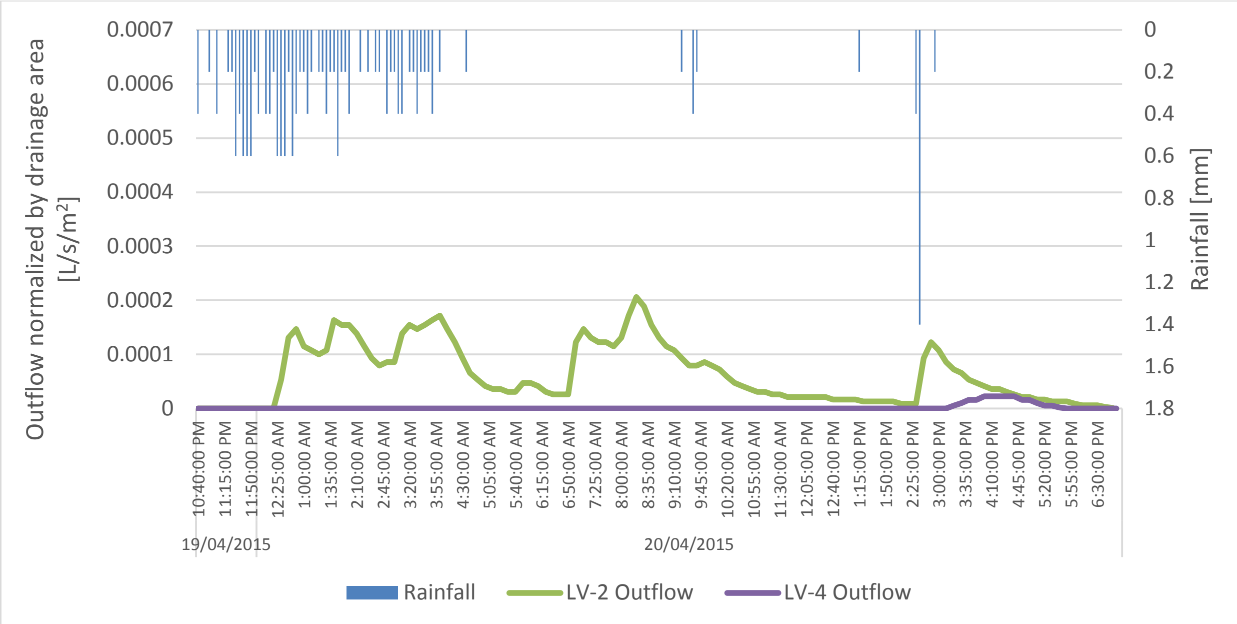


Figure 4-4 Hydrograph for April 19 2015 (20 mm)

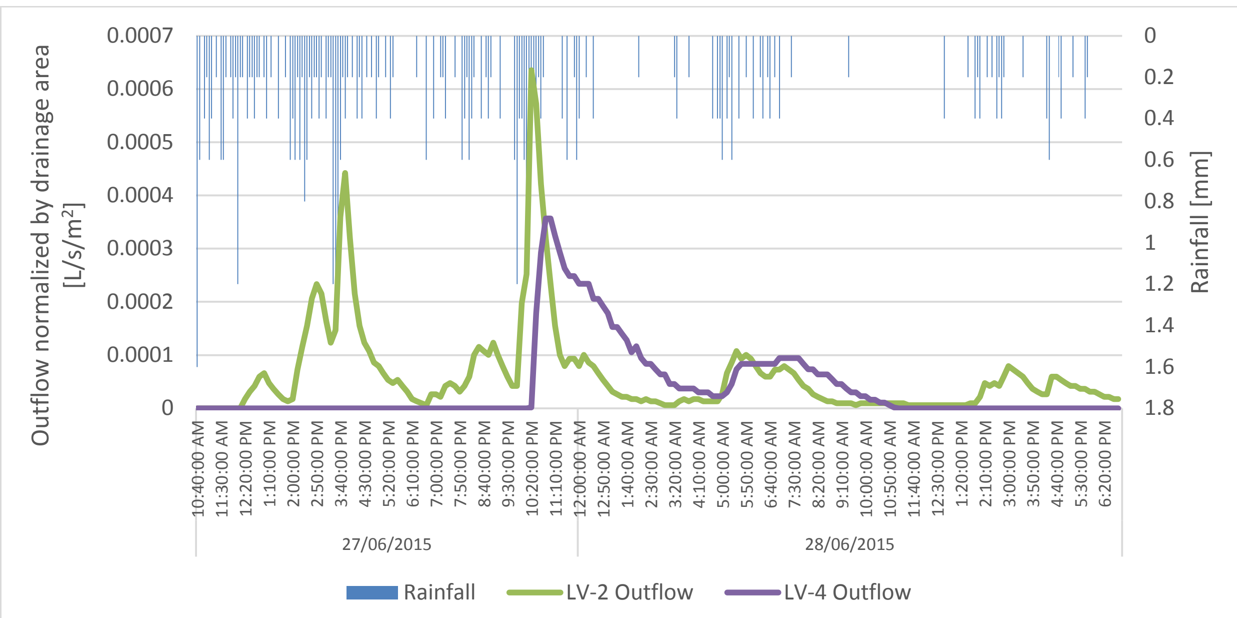


Figure 4-5 Hydrograph for June 27 2015 (54 mm)

The peak outflow from the green street (LV-4) was delayed and further attenuated compared to the traditional grass swales (LV-2). The volume of outflow (per unit drainage area) from the green street was much smaller than LV-2. Intervals of high precipitation magnitude and intensity were required to generate outflow from the green street as it has a more natural hydrologic response than traditional stormwater management (**Figure 4-2**).

4.2.3 Response to Large Events

Low impact development practices provide storage and can help to reduce peak flows during less frequent events, which helps to prevent surcharging of downstream pipe infrastructure. The cumulative storage that can be provided by extensive LID implementation, has the potential to reduce watercourse flooding as well. The percent peak flow reductions achieved for storms larger than the 2 yr event are summarized in **Table 4-5**.

Table 4-5 Peak flow reductions for events larger than 2 yr (33 mm) at LV-4

Event Date	Total precipitation depth (mm)	Peak intensity (mm/hr)	Precipitation duration (hr:min)	Peak to peak lag (hr)	Peak flow reduction (percent)	Depth retained (mm)
>50 y (71 mm)						
Jul 8 2013	81.6	214.8	5:40	0.33	24.7	44.4
5 – 10 y events (45 – 55 mm)						
May 30 2015	47.8	36.0	32:40	N/A	100	47.8
Jun 27 2015	54.0	13.2	31:00	12.2	74.3	49.3
2-5 y events (33 – 45 mm)						
Sep 8 2012	38.4	39.6	9:20	N/A	100	38.4
Jun 10 2013	33	26.4	19:30	4	97.3	32.6
Apr 29 2014	41.4	14.4	34:30	3.2	77.5	37.8
Jul 27 2014	33.6	10.8	15:40	8.5	83.1	32.2
Sep 5 2014	34	31.2	9:10	6.2	90.6	30.3

Note: The depths for each return period are based on the four-hour Chicago storm event. Events affected by snow accumulation or melt not included.

The storage provided by low impact development systems is also expected to provide a delay in outflow. The “lag” in outflow is often reported as the time between the “midpoints” of rainfall (volume) and outflow (volume). For this study, CVC was interested in the “lag” between the occurrence of peak rainfall and peak outflow rates. These two approaches yield different results. For the June 28, 2015 event illustrated above, the peak outflows from LV-2 and LV-4 were delayed by 11.7 and 12.2 hours, respectively, using the “peak to peak” approach. The midpoints of the outflow volume were delayed 4 and 5.4 hours after the midpoint of the rainfall volume for LV-2 and LV-4, respectively. In general, the calculated lags were variable and highly dependent on the rainfall distribution. Some events had a large proportion of rain early in the event, but the highest rainfall intensity occurred later. In these cases, the peak outflow could precede the peak rainfall, yielding a negative lag time. This occurred at LV-2 for the April 19 event illustrated above which had a “peak to peak” lag of -6.2 hours. The “volume midpoint” lag for LV-2 for this event was 4.1 hours. The “peak to peak” and “volume midpoint” lags for LV-4 on April 19, 2015 were 1.5 and 13.4 hours, respectively.

Although events up to 25 mm are the focus for volume reduction and objectives related to water balance and water quality, the volume reduction that can be achieved for large events is also of interest. The percentage volume reductions achieved for large events are shown in **Figure 4-5** and **Figure 4-6**, which are discussed in the next section.

4.2.4 Assessment of Volume Reduction

Volume reduction is achieved by retaining water (through infiltration or evapotranspiration) such that it does not contribute to outflow from the site. It is important for groundwater recharge and water balance objectives as well as water quality objectives. In addition, retention of stormwater is an effective means of meeting erosion control objectives. Only 14 events produced outflow from the LID site (LV-4). Many more outflow events (129) were observed from the traditional grass swales (LV-2). The overall runoff volume reduction for LV-2 and LV-4 were 68.1 and 92.1 per cent. The runoff volume reductions achieved for events of different sizes are provided below in **Figure 4-5** and **Figure 4-6.** For small events (up to 25 mm), the volume reductions were 76.6 and 99.7 per cent for LV-2 and LV-4 respectively.

LID facility monitoring is important to assess whether a facility was constructed properly and is functioning as designed prior to taking ownership. Construction issues that may arise are not always evident from visual inspection. Monitoring can provide insight into what is happening below the surface. The curb-cut inlets were found to be an issue at Lakeview. Evaluation of the collected water level and flow data indicated the facility was not receiving the quantity of water anticipated based on precipitation data. CVC staff filmed a heavy rainfall event to document the problem. Without monitoring at this site the inlet grading issues would not have been noticed as quickly and stormwater control benefits would have been lost. Upon alteration of the inlets in the Fall of 2016, the LID facilities will then be able to accept and treat more stormwater runoff, diverting it from the municipal stormwater system and more closely resembling natural hydrologic conditions (**Figure 4-2**).

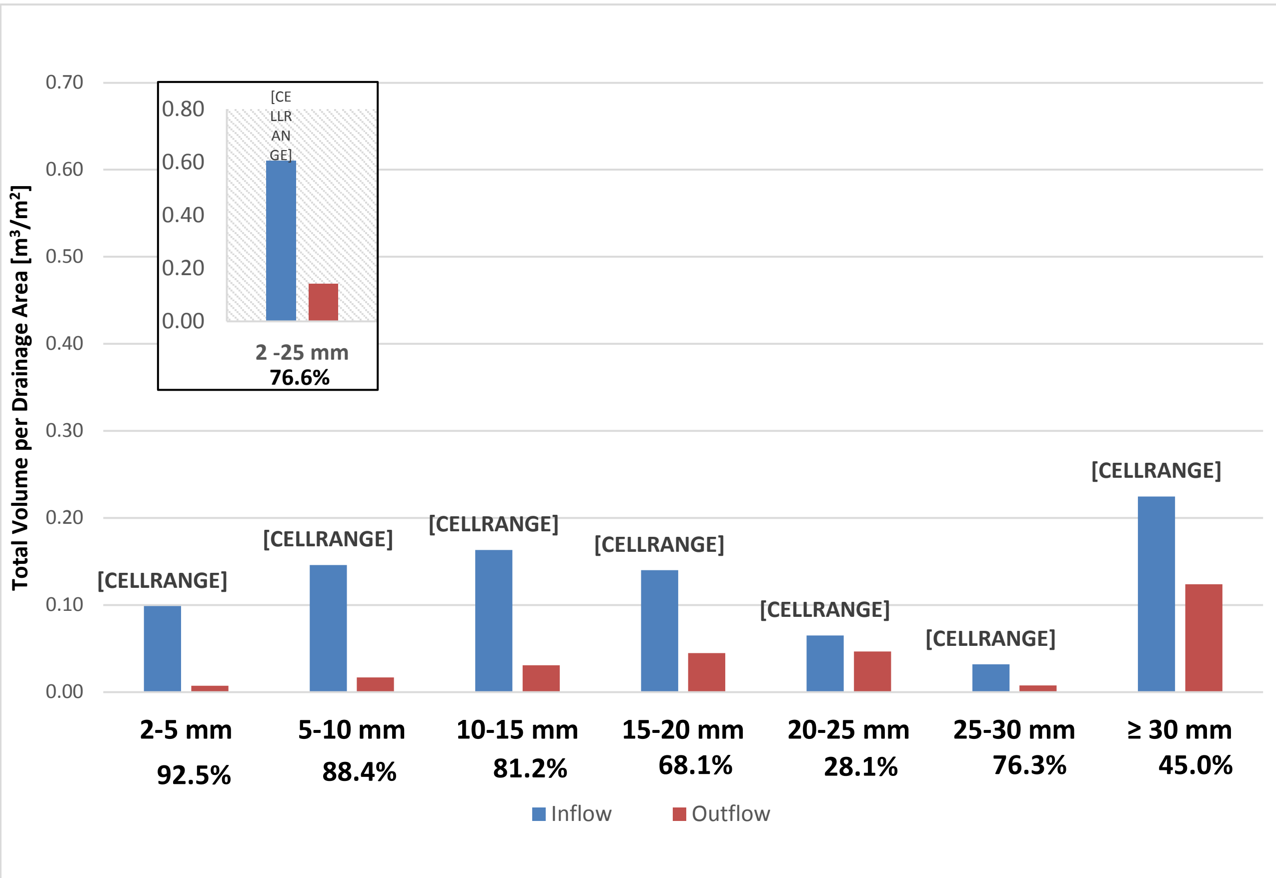


Figure 4-6 Runoff volume reduction achieved at LV-2, for different event size ranges, 2012 to June 2015

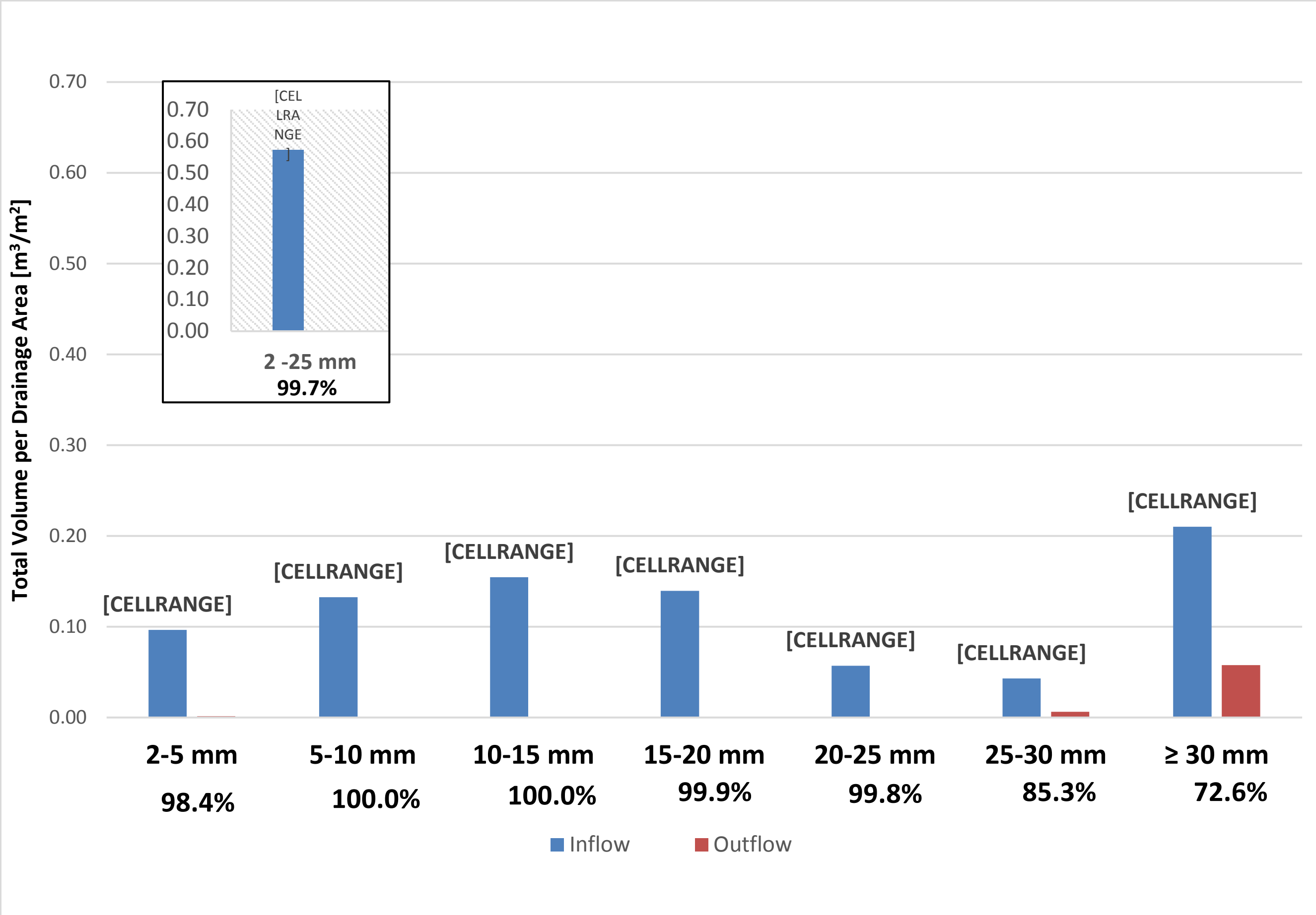


Figure 4-7 Runoff volume reduction achieved at LV-4, for different event size ranges, 2012 to June 2015

On an event basis, volume reductions based on measured precipitation and outflow can be affected by snow accumulation and melt. The analysis was repeated using only events from mid-April through November. The volume reductions for events up to 25 mm were 81.3 per cent and 100 per cent for LV-2 and LV-4, respectively using this subset of the data. The largest discrepancy was observed in the 20-25 mm size class for LV-2. The discrepancy can be largely attributed to a particularly low percent volume reduction estimated for the February 11, 2013, due to substantial melt. Melt that was associated with a small (3.8 mm) precipitation event on Jan 30, 2013 was responsible for the only outflow associated with a small event at LV-4.

Aside from the January 30 2013 event, the smallest event to produce outflow at LV-4 was a 20 mm event on April 19 2015. The behavior of the traditional grass-lined ditch was distinct in this regard, producing outflow for most events smaller than 20 mm and many events smaller than 10 mm.

The retention observed from the green street exceeds the CVC stormwater management erosion control criteria to detain 5 mm on site. **Figure 4-6** also presents the depth retained for 2 yr and less frequent events. The smallest retention depth obseved for events in the size range of particular concern for erosion, was 30.3 mm (for a 34 mm event on September 5, 2014). For comparison, the CVC erosion control criteria for new development with a stormwater management pond is to detain 25 mm for 48 hrs.

4.2.5 Water Levels and Ponding Depths

Bioswale water levels are monitored on the south and north side of the green street. **Figure 4-8** shows the water levels measured at this location during 2014. The invert of the underdrain is 0.5 m above the base of the system (about 1.2 m below ground surface). In 2014, more than 15 mm of precipitation was required to fill the storage below the underdrain at this location. Outflow was only generated for events with more than 30 mm of precipitation during 2014. The underdrain may have conveyed water to locations with more storage capacity for events between 15 and 30 mm.

The dark blue line indicates the water level in meters below ground surface. The orange diamonds are manual measurements that were taken by field staff to both ensure the logger is recording the correct water level, and to adjusted the data if needed.

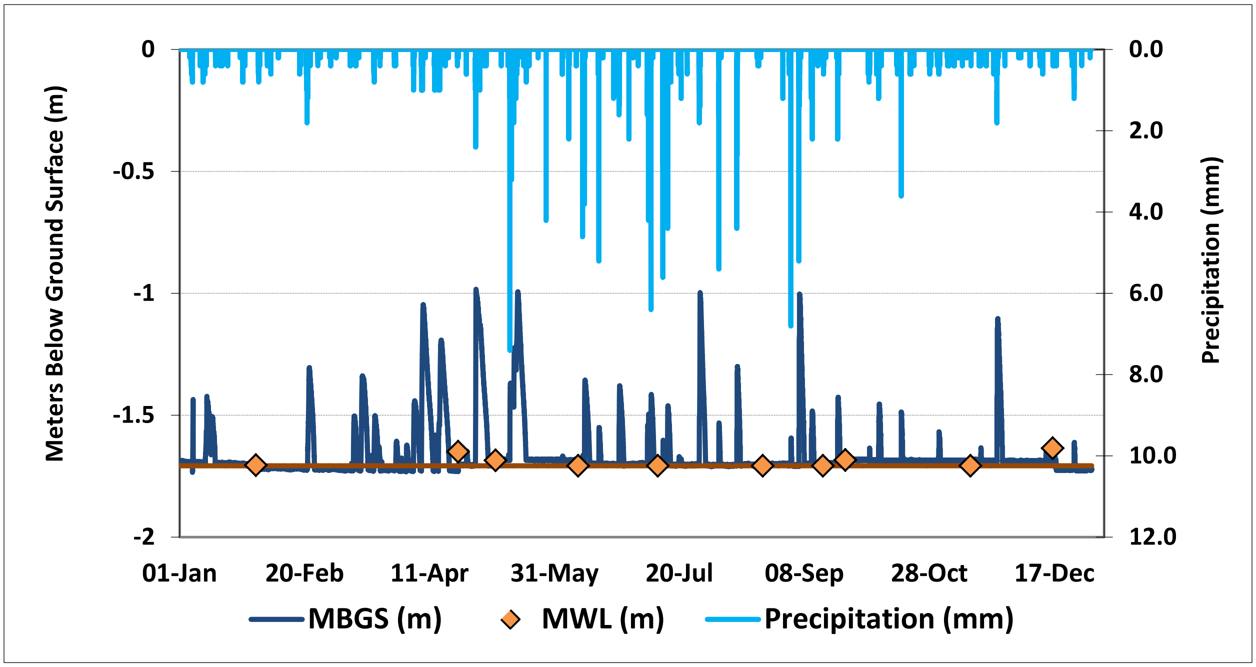


Figure 4-8 Water levels in bioswales during 2014

4.3 Water Quality

Stormwater quality controls are important in order to prevent the degradation of water quality in receiving water bodies. CVC's Stormwater Management Criteria (CVC 2012) stipulates that all watercourses and water bodies (e.g. Lake Ontario) within CVC's jurisdiction require, at a minimum, an enhanced level of protection (i.e. 80 per cent TSS removal). For the last three decades, end-of-pipe wet facilities (i.e. wet ponds, wetlands, or hybrid pond/wetlands) have been used for water quality control. In conventional end-of-pipe wet stormwater management facilities, the main treatment mechanism for suspended solids is settling. This mechanism is less effective for removing smaller particles and other contaminants are often associated with these small particles. In addition, contaminants that are dissolved in stormwater may pass through conventional stormwater facilities without being treated.

CVC's Water Quality Strategy (CVC 2009) identifies parameters of concern (PoC) for which provincial or federal water quality objectives have been set (**Table 4-6)**. **Table 4-6** summarizes PWQOs for many of the parameters that are being monitored at the Lakeview site. Although these objectives were not specifically developed for stormwater discharges, the U.S. EPA, Environment Canada and the MOECC recognize that urban stormwater is a major contributor to pollutant loading on our rivers and the Great Lakes. Stormwater treatment facilities are needed to control discharges of PoCs to receiving waters.

The Cooksville Creek watershed was developed without stormwater management control facilities and it is now fully developed with limited to no available space for introducing SWM control ponds. Therefore, implementing smaller, distributed LID facilities that provide additional water quality control at the source is one of the best options to help meet the water quality objectives laid out in CVC's Stormwater Management Criteria.

The water quality performance of LID practices is best measured as load reduction, which takes into account volume and pollutant reduction mechanisms. As discussed in the previous section, the green street retrofit in the Lakeview area achieved good volume reduction. For events up to 25 mm in size, which are cumulatively responsible for most of the annual pollutant load on watercourses, stormwater runoff volume was nearly eliminated. This is in contrast to conventional BMPs such as retention ponds that do not provide substantial volume reduction and therefore, depend upon contaminant removal to achieve mass load reductions. For all events that achieve 100 per cent volume reduction, no contaminant mass leaves the system in outflow such that these events do not contribute to contaminant loads via a surface pathway.

Event mean concentrations (EMCs) are the flow-proportional average concentrations of water quality parameters during a storm event.

The EMCs and the runoff volume determine the pollutant loads from a site and are representative of average pollutant concentrations over a runoff event.

Pollutant removal is also important in LID systems. Pollutant removal mechanisms in permeable pavement and bioretention systems include settling, filtration, and adsorption. Contaminants that are removed by these mechanisms are retained within the treatment system. Biologically mediated transformations can also occur between nitrogen species with the potential for nitrogen to be released to the atmosphere.

The following section presents the water quality performance results for the Lakeview green street retrofit. Effluent concentrations for the green street retrofit (LV-4) will be compared to measured influent concentrations at the LV-1 control site, effluent concentrations from similar LID practices in other locations, and effluent concentrations from the traditional grass swale system (LV-2) within the study area. These comparisons can provide insights into preferred designs and advancements which may be needed.

Table 4-6 Provincial Water Quality Objectives (PWQOs) for selected metals, nutrients and other parameters of interest

Parameter	Unit	PWQO
Metals		
Cadmium (Cd)	µg/L	0.2
Copper (Cu)	µg/L	5
Iron (Fe)	µg/L	300
Lead (Pb)	µg/L	1 – 5 depending on hardness (Interim)
Nickel (Ni)	µg/L	25
Zinc (Zn)	µg/L	20 (Interim revised)
Nutrients		
Total Phosphorus (TP)	µg/L	30
Nitrate-Nitrogen (NO_3 as N)	mg/L	3.0 (CCME)
Nitrite + Nitrate (NO_2 + NO_3)	mg/L	N/A
Other		
Temperature	°C	Narrative standard, with some numeric components
Total Suspended Solids (TSS)	mg/L	25 (CCME)

Sources: Water Management Policies, Guidelines, Provincial Water Quality Objectives of the Ministry of the Environment (July 1994, Reprinted February 1999), Canadian Environmental Quality Guidelines. Canadian Council of Ministers of the Environment. (2001).

4.3.1 Influent Concentrations

Samples from LV-1 were collected and analyzed to characterize the water quality of stormwater runoff in the Lakeview area. The results of 50 water quality samples were included in the analysis of the water quality from LV-1. Ten of these samples which were collected between December 1 and April 15 were used to characterize “winter” water quality. The median EMCs calculated for LV-1 are presented in **Table 4-7**. The median EMC from LV-1 is the median influent EMC in **Table 4-8.**

Table 4-7 LV-1 Water Quality for Control Site

Parameter (units)	Median EMC	Median “summer” EMC	Median “winter” EMC
Total Suspended Solids (mg/L)	46.5	35.0	73.50
Total Dissolved Solids (mg/L)	99.0	86.0	266.0
Nutrients			
Total Phosphorous (mg/L)	0.26	0.26	0.27
Ortho-phosphate (mg/L)	0.13	0.14	0.10
TKN (mg/L)	1.35	1.25	1.55
Nitrate + Nitrite (m/L)	0.31	0.29	0.60
Ammonia (mg/L)	0.29	0.22	0.39
Metals			
Cd (µg/L)	0.19	0.17	0.26
Cu (µg/L)	15.7	14.90	18.30
Fe (µg/L)	537.5	476.50	1175.0
Pb (µg/L)	7.11	4.12	15.00
Ni (µg/L)	1.75	1.50	3.30
Zn (µg/L)	67.50	53.85	108.50

4.3.2 Effluent Concentrations

Seven composite samples were collected from LV-4 between 2012 and 2015, including one “winter” sample collected January 30, 2013. All seven samples were included to calculate the median EMCs summarized in **Table 4-9.** The median values were very similar with and without the January 2013 sample. Analyses for thirty-eight composite samples were available for LV-2, all of which were collected between April and November.

The results are also compared to typical effluent EMC achieved by similar LIDs, as per the BMPDB. The BMPDB values represent LIDs that are used to treat stormwater runoff from a range of land uses.

Table 4-8 Summary of effluent EMC results

System	LV-1 Water Quality Control Site	LV-2 Traditional Grass Swales	LV-4 LID Retrofit	Bioretention BMPDB
Parameter (units)	**Median influent EMC**	**Median effluent EMC**	**Median effluent EMC**	**Median effluent EMC**
Total Suspended Solids (mg/L)	46.5	39.0	14.0	9.9
Total Dissolved Solids (mg/L)	99.0	141.0	346	NA
Nutrients				
Total Phosphorous (mg/L)	0.26	0.25	0.35	0.24
Ortho-phosphate (mg/L)	0.13	0.15	0.27	0.26
TKN (mg/L)	1.35	1.25	1.70	1.34
Nitrate + Nitrite (mg/L)	0.31	0.57	1.69	0.39
Ammonia (mg/L)	0.29	0.24	0.15	NA
Metals				
Cd (µg/L)	0.19	0.17	0.12	0.07
Cu (µg/L)	15.7	17.65	14.30	5.33
Fe (µg/L)	537.5	439	300.0	1,027
Pb (µg/L)	7.11	5.93	2.81	0.19
Ni (µg/L)	1.75	1.20	14.10	4.53
Zn (µg/L)	67.50	47.0	15.60	12.0

The effluent concentration results for selected parameters are also shown in **Figure 4-8** to **Figure 4-11**. **Figure 4-8** and **Figure 4-9** are time series, with the concentration of each sampled event plotted, for two groups of parameters. **Figure 4-10** and **Figure 4-11** include probability plots which show the percentage of samples with concentrations below different values. The median concentration occurs at 50 per cent. These figures also include a "box and whisker" plot where the horizontal line in the middle of the box is the median concentration, the lower and upper sides of the box are the 25^{th} and 75^{th} percentile values and the whiskers extend to the 5^{th} and 95^{th} percentile values.

Nickel was identified as having a much higher event mean concentration at LV-4 (LID site) compared to the traditional grass swales and curb and gutter. Soil sampling was conducted on the street with the bioretention units and samples were collected from multiple units. The results were all negative for nickel in the bioretention soils, meaning that there must be a historical reason for this nickel concentration at LV-4. Further investigation is required, but this elevated concentration is not seen at any of the other Lakeview monitoring locations. Due to a high amount of industrial activity along Lakeshore in the past, there could have been a source of nickel that still remains, but despite the higher concentrations of nickel at LV-4 this metal still remains below the Provincial Water Quality Objective of 25 μg/L.

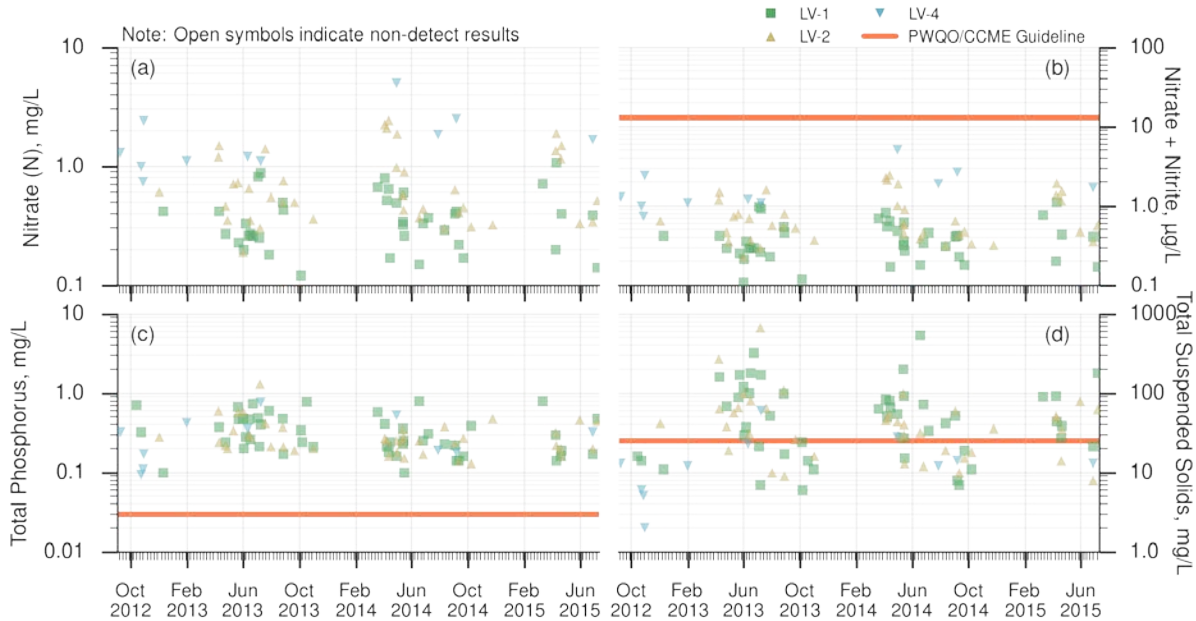


Figure 4-9 Time series of effluent concentrations for selected parameters

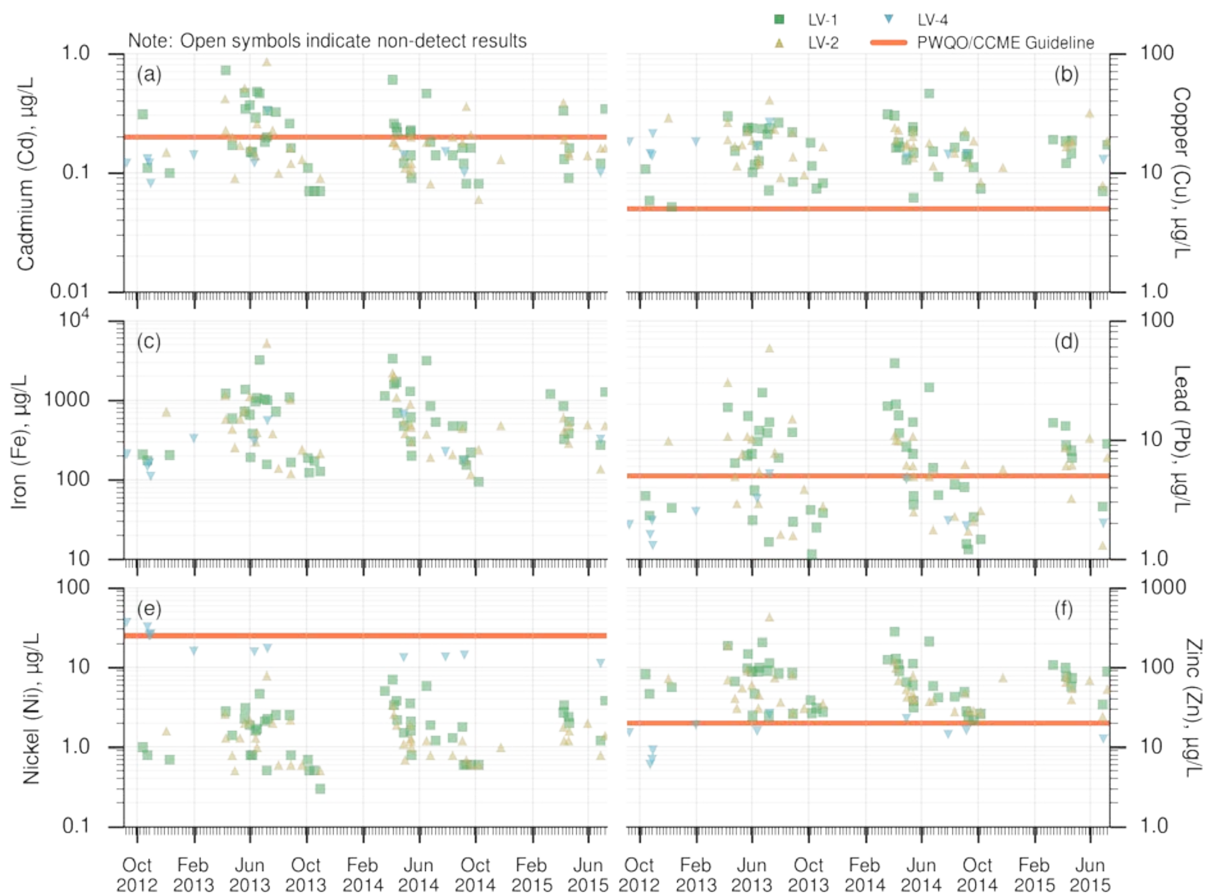


Figure 4-10 Time series of effluent concentrations for selected metals

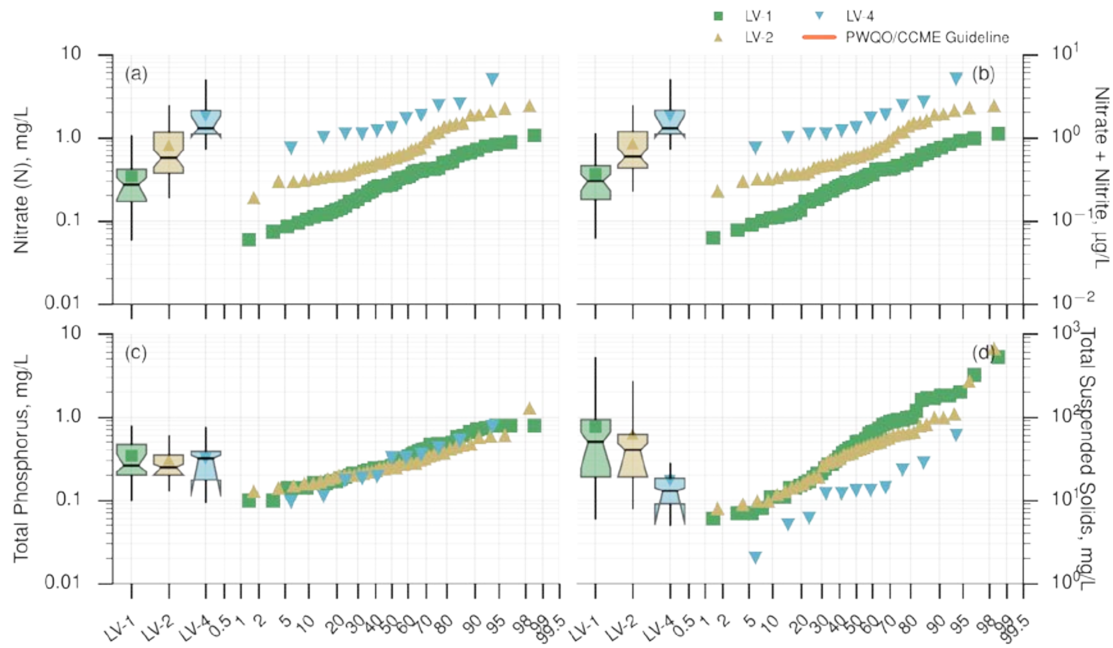


Figure 4-11 Probability plots of effluent concentrations for selected parameters

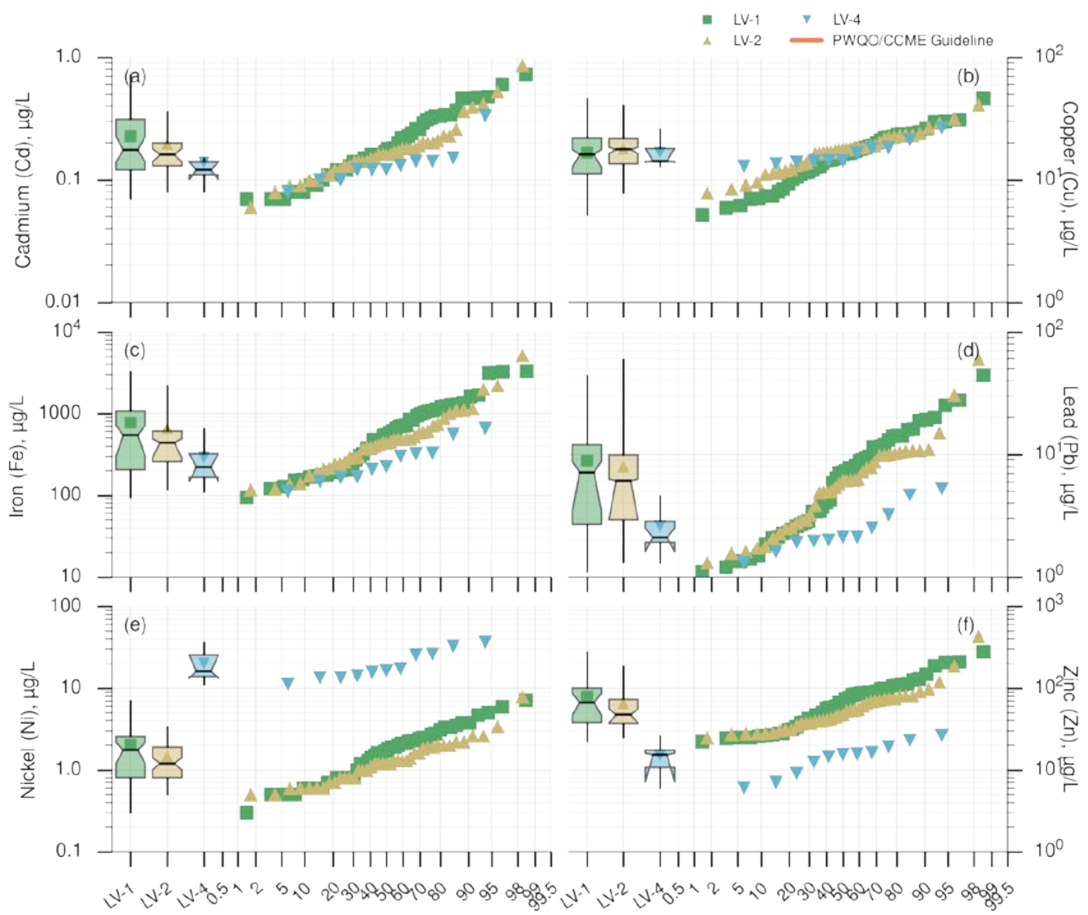


Figure 4-12 Probability plots of effluent concentrations for selected metals

In comparison to the controls, effluent from LV-4 had lower TSS, higher nitrate and TKN and slightly higher total phosphorous concentrations. It is believed this is an artifact of the smaller sample size as the LV-4 bioswales only flow for events greater than 20 mm, resulting in some washout of organic materials in dissolved form. The filter media placed within the bioswales includes some organic material which can be a source of nutrients, particularly in the dissolved form. Concentrations of lead and zinc are distinctly lower in the effluent from LV-4, compared to the control sites.

While separate EMC were calculated for "winter" and "summer" events for the control site LV-1, this was not merited for LV-2 and LV-4 based on the available information. A summary of the available seasonal information for selected parameters is presented in **Table 4-10**. The limited seasonal water quality data for LV-2 and LV-4 provides some evidence of distinct quality for samples from mid-November through mid-April. The concentrations of total dissolved solids, chloride and sodium in the effluent are higher. These are the parameters most directly correlated with road salt application. Higher concentrations of metals, including iron and zinc, were measured in the early April samples from LV-2, similar to the findings at LV-1.

Table 4-9 Comparison of winter season effluent quality for selected parameters

Season	TSS (mg/L)	TDS (mg/L)	Chloride (mg/L)	Sodium (mg/L)	Zinc (ug/L)
LV-1					
Late November through Early April (10)	73.5	266.0	110.0	78.9	108.5
Late April through Early November (40)	35.0	86.0	9.50	8.6	53.85
LV-2					
Late November through Early April (6)	50.0	332	115	76.3	77.25
Late April through Early November (18)	31.5	115	17.5	19.0	40.7
LV-4					
January (1)	5	712	190	140	12.3
June to September (5)	18.50	340	33.5	36.9	15.8

4.3.3 Contaminant Load Reductions

The inflow loads were calculated using the median event mean concentrations measured at the control site (LV-1) and the inflow volumes estimated using the simple method for LV-2 and LV-4. To calculate outflow loads, the event mean concentrations for a particular event were used if the event was sampled and analyzed. If no lab analyses were available for a particular event at LV-2 or LV-4, median event mean concentrations for the system were used. **Table 4-11** provides the mass load reduction results calculated for parameters of concern.

The analysis includes both events that generated outflow and events that did not. The high overall mass load reduction for LV-4 is not surprising since only 14 events produced outflow from this system. LV-4 achieved more than 90 per cent mass removal of TSS and all of the metals, except nickel. In comparison, LV-2 achieved between 65 and 78 per cent mass removal of TSS and the metals included in the analysis. The 72 per cent mass reduction of TSS by LV-2 falls short of the CVC requirement for 80 per cent removal of TSS.

Table 4-10 Percentage Load Reductions

System	LV-4			LV-2		
Parameter	Normalized Inflow Load (mg)	Normalized Outflow Load (mg)	Estimated Load Reduction (%)	Normalized Estimated Inflow Load (mg)	Normalized Outflow Load (mg)	Estimated Load Reduction (%)
Total Suspended Solids	38860	2670	93.1%	40300	11129.38	72.4
Total Phosphorous	217.4	38.0	82.5	226.8	70.09	69.1
Ortho-Phosphate	105.4	31.8	69.8	110.2	41.97	61.9
TKN	1110	153.6	86.2	1157	366.55	68.3
Nitrate + Nitrite	319.7	104.6	67.3	331.6	283.42	14.5
Cadmium	0.164	0.016	90.5	0.170	0.05	71.7
Copper	13.19	1.38	89.5	13.74	4.80	65.0
Iron	574.1	30.1	94.8	594.6	155.73	73.8
Lead	6.21	0.27	95.6	6.42	1.91	70.3
Nickel	1.70	1.04	38.6	1.77	0.38	78.2
Zinc	58.6	1.42	97.6	60.8	15.44	74.6

Figure 4-13 and **Figure 4-14** show the influent and effluent mass loads of total phosphorous based on event size, for LV-2 and LV-4, respectively.

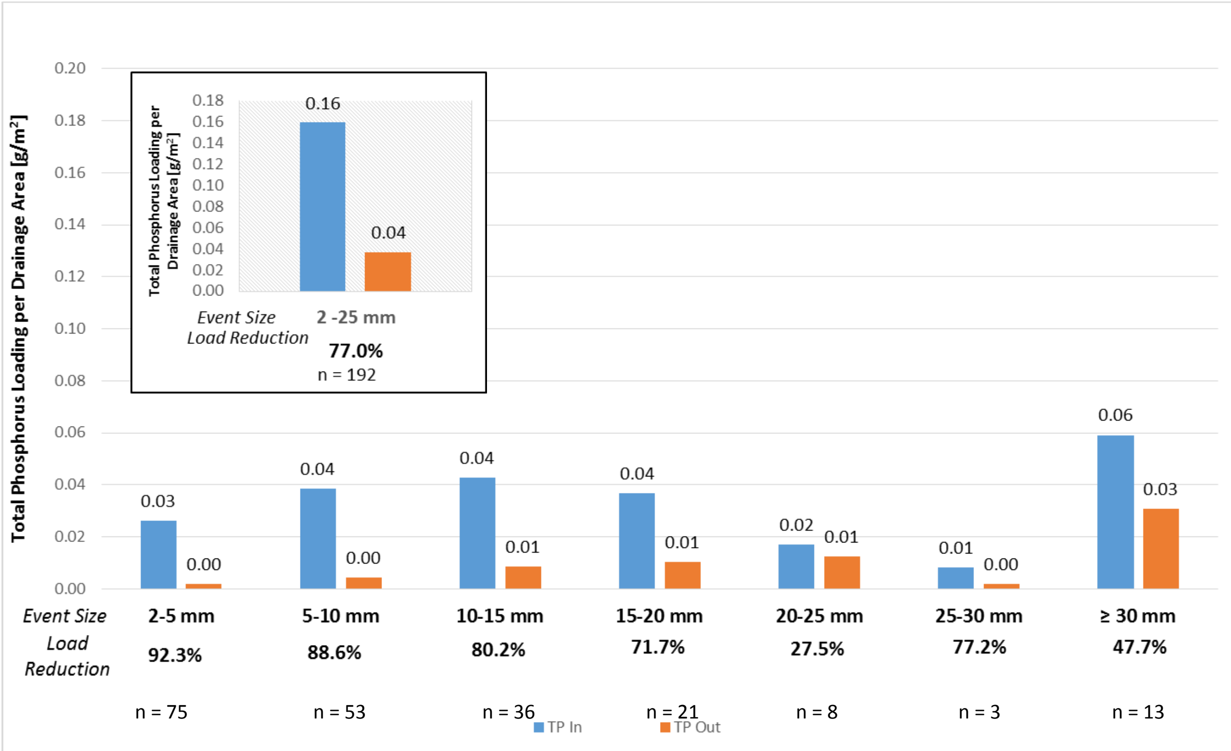


Figure 4-13 Total Phosphorous load reduction achieved by LV-2 for different event sizes

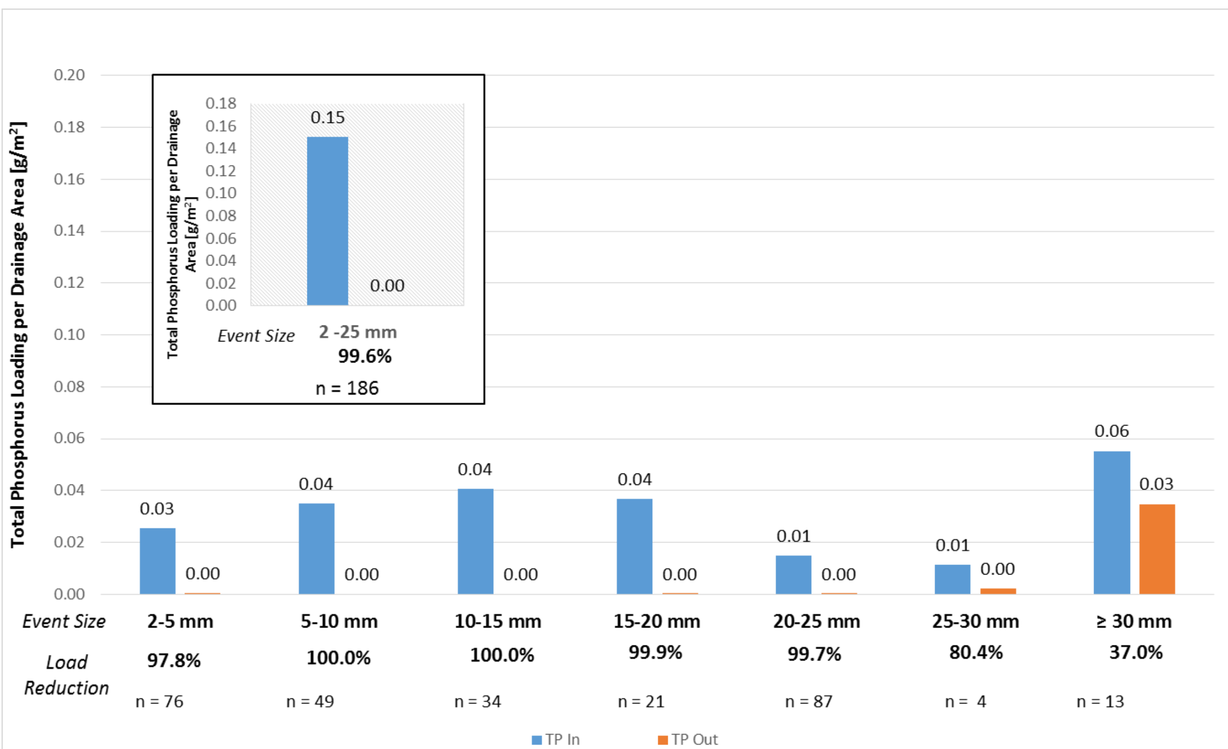


Figure 4-14 Total Phosphorous load reduction achieved by LV-4 for different event sizes

The large number of no flow events from LV-4 also led to good overall mass load reduction of phosphorous (83 per cent). On an event basis, mass removal of phosphorous was achieved for most events. However, negative mass removal rates were calculated for two events, including the large July 8, 2013 event. It is possible for phosphorous accumulated in the system during previous events to be flushed out. LV-2 also had good mass reduction of total phosphorous (69 per cent). The mass reduction of ortho-phosphate, the major dissolved form of phosphorous, was slightly lower in both LV-4 and LV-2 (70 and 62 per cent, respectively).

4.4 Soil Analysis

The LID approach at Lakeview aims to minimize runoff and pollutants though the combination of permeable pavement and bioretention cells. Rainwater alone contains trace amounts of pollutants; however stormwater runoff plays a key role in contaminant transport. This is particularly evident in winter as a result of winter road maintenance activities when anthropogenic sources of soluble salts (deicing salt constituents) are transported to soils. Bioretention swales use plants and engineered filter media to chemically, physically and biologically treat pollutants. Soil sampling will help track contaminants and aid in evaluating the frequency of maintenance activities such as filter media replacement.

4.4.1 Soil Sampling Methodology

Soil sampling occurred in the bioretention units that receive runoff from the LV-4 catchment area. **Figure 4-15** shows the bioswales that samples were collected from. Sampling occurred October 9, 2014 after summer precipitation events but prior to the ground freezing. Soil (filter media) sampling was conducted at two depths. Samples were analyzed by Maxxam Analytics for metals, inorganics, and polyaromatic hydrocarbons (PAHs).

Figure 4-15 Soil sampling locations in the Lakeview bioswales

Two composite soil samples were collected from three bioretention cells (six samples total). The shallow and deep samples were collected at approximately 5 cm and 30 cm below the filter media surface, respectively. In the sampled cells, three subsamples from each depth were combined to produce one composite sample. Comparison between two sampling depths provides information regarding the depth at which pollutant removal occurs for different parameters. In addition, sampling at two depths helps determine whether or not pollutants are migrating through the soil column over time. Collecting samples from multiple bioretention cells will provide insight on pollutant removal for different plant combinations and how parameter concentrations vary depending bioretention cell location (i.e. different water volume inputs). Ideally, soil sampling for contaminant tracking will occur biennially. The next soil sampling event for Lakeview is scheduled for Fall 2016.

Soil quality results were compared to CCME Soil Quality Guidelines for the Protection of Environmental and Human Health (CCME, 2014) and to the Environmental Protection Act, Ontario Reg. 153/04 Table 7: Generic Site Condition Standards for Shallow Soils in a Non-Potable Ground Water Condition Soil - Coarse Texture (MOE, 2011) for the appropriate land use.

4.4.2 Soil Sampling Results

The concentrations of the soil quality parameters that correspond to the defined water quality parameters of interest are summarized in **Table 4-11**, results for all parameters tested are in **Table 4-12.** All results fell below the applicable CCME, 2014 and MOE, 2011 soil condition standards for parameters that had guidelines available.

Although many parameters had concentrations below the detection limit, there are a couple trends in the soil results for the parameters of interest. The concentration of Total Kjeldahl Nitrogen was higher in the upper soil layer in all bioretention units that were sampled. Conversely, for the metals, Iron had an increase in concentration in the deeper soil layer. PAH compounds (**Table 4-12**) also had many concentrations below the detection limit. Two out of the three bioretention units that were sampled had PAH concentrations that were generally higher in the upper soil layer; this trend is consistent with what we are seeing at other study sites (Elm Drive and IMAX). It is difficult make direct comparisons regarding contaminant concentrations between bioretention cells because the cells have different plant combinations and receive varying volumes largely depending on bioswale inlet locations. Future soil sampling will show if concentrations increase with time. Since the concentrations of contaminants were well below the specified guidelines, the bioswales in the LV-4 drainage area have not been contaminated by stormwater runoff.

Table 4-11 Soil Quality Parameters of Interest that correspond to the defined Water Quality Parameters of Interest

Parameter	Units	Detection Limit	CCME Guideline (Residential/ Parkland)	MOE Guideline (Shallow Soil, Not Potable, Residental/Parkland/Institutional, Coarse Texture)	Bioswale 1 Shallow	Bioswale 1 Deep	Bioswale 2 Shallow	Bioswale 2 Deep	Bioswale 3 Shallow	Bioswale 3 Deep
Cadmium	ug/g	0.5	10	1.2	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50
Copper	ug/g	2.0	63	140	11	11	11	11	11	10
Iron	ug/g	50.0	*	*	7100	8100	8800	9200	8200	8800
Lead	ug/g	5.0	140	120	<5.0	<5.0	5.7	<5.0	<5.0	<5.0
Nickel	ug/g	5.0	45	100	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0
Zinc	ug/g	5.0	200	340	25	24	30	28	25	23
Orthophosphate	ug/g	0.2	*	*	10	9	11	11	9.3	8.6
Total Kjeldahl Nitrogen	ug/g	10.0	*	*	2100	1350	2040	1760	2000	1730
Nitrate + Nitrite	ug/g	3.0	*	*	<3	<3	<3	<3	<3	<3

*** indicates no guideline available**

Table 4-12 All Soil Parameters tested at Lakeview October 2014

	Parameter	Units	Detection Limit	CCME Guideline (Residential/ Parkland)	MOE Guideline (Shallow Soil, Not Potable, Residental/Parkland/Institutional, Coarse Texture)	Bioswale 1 Shallow	Bioswale 1 Deep	Bioswale 2 Shallow	Bioswale 2 Deep	Bioswale 3 Shallow	Bioswale 3 Deep
	Total Ammonia-N	ug/g	25	*	*	<25	<25	<25	<25	<25	<25
	Soluble (20:1) Chloride (Cl)	ug/g	20	*	*	<20	<20	<20	<20	<20	<20
	Conductivity	umho/cm	1	*	700	159	178	161	203	180	168
	Orthophosphate (P)	ug/g	0.2	*	*	10	9	11	11	9.3	8.6
Inorganics	Available (CaCl2) pH	pH	N/A	*	*	7.02	7.11	6.86	7	6.95	6.94
	Total Kjeldahl Nitrogen	ug/g	10	*	*	2100	1350	2040	1760	2000	1730
	Nitrite (N)	ug/g	0.5	*	*	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
	Nitrate (N)	ug/g	2	*	*	<2	<2	<2	<2	<2	<2
	Nitrate + Nitrite	ug/g	3	*	*	<3	<3	<3	<3	<3	<3
	Acid Extractable Aluminum (Al)	ug/g	50	*	*	2400	2500	2600	2600	2500	2500
	Acid Extractable Barium (Ba)	ug/g	2	500	390	24	25	29	27	24	24
	Acid Extractable Beryllium (Be)	ug/g	0.5	4	4	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50
	Acid Extractable Cadmium (Cd)	ug/g	0.5	10	1.2	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50
	Acid Extractable Calcium (Ca)	ug/g	500	*	*	25000	24000	22000	24000	22000	23000
	Acid Extractable Chromium (Cr)	ug/g	1	64	160	6.2	6.8	6.8	7.4	6.4	6.3
	Acid Extractable Cobalt (Co)	ug/g	2	50	22	<2.0	2.3	2.2	2.3	2.1	2.2
	Acid Extractable Copper (Cu)	ug/g	2	63	140	11	11	11	11	11	10
	Acid Extractable Iron (Fe)	ug/g	50	*	*	7100	8100	8800	9200	8200	8800
	Acid Extractable Lead (Pb)	ug/g	5	140	120	<5.0	<5.0	5.7	<5.0	<5.0	<5.0
	Acid Extractable Magnesium (Mg)	ug/g	50	*	*	2800	3000	3000	3200	3000	2900
Metals	Acid Extractable Manganese (Mn)	ug/g	1	*	*	120	130	130	130	120	130
	Acid Extractable Molybdenum (Mo)	ug/g	2	10	6.9	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0
	Acid Extractable Nickel (Ni)	ug/g	5	45	100	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0
	Acid Extractable Phosphorus (P)	ug/g	20	*	*	550	550	630	640	590	550
	Acid Extractable Potassium (K)	ug/g	200	*	*	540	700	510	680	600	500
	Acid Extractable Silver (Ag)	ug/g	1	20	20	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
	Acid Extractable Sodium (Na)	ug/g	100	*	*	<100	<100	<100	130	<100	<100
	Acid Extractable Strontium (Sr)	ug/g	1	*	*	37	36	36	37	35	35
	Acid Extractable Sulphur (S)	ug/g	50	*	*	290	300	340	340	300	290
	Acid Extractable Tin (Sn)	ug/g	20	50	*	<20	<20	<20	<20	<20	<20
	Acid Extractable Vanadium (V)	ug/g	5	130	86	14	17	19	19	18	19
	Acid Extractable Zinc (Zn)	ug/g	5	200	340	25	24	30	28	25	23
	Acenaphthene	ug/g	0.005	*	7.9	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050
	Acenaphthylene	ug/g	0.005	*	0.15	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050
	Anthracene	ug/g	0.005	*	0.67	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050
	Benzo(a)anthracene	ug/g	0.005	*	0.5	0.017	0.015	0.023	0.052	0.048	0.013
	Benzo(a)pyrene	ug/g	0.005	0.7	0.3	0.033	0.026	0.042	0.08	0.069	0.025
	Benzo(b/j)fluoranthene	ug/g	0.005	*	0.78	0.072	0.054	0.079	0.13	0.12	0.06
	Benzo(g,h,i)perylene	ug/g	0.005	*	6.6	0.045	0.034	0.044	0.079	0.069	0.034
	Benzo(k)fluoranthene	ug/g	0.005	*	0.78	0.02	0.015	0.024	0.04	0.038	0.015
	Chrysene	ug/g	0.005	*	7	0.024	0.022	0.03	0.058	0.055	0.023
PAH	Dibenz(a,h)anthracene	ug/g	0.005	*	0.1	0.0074	0.0054	0.0085	0.014	0.012	0.0058
	Fluoranthene	ug/g	0.005	*	0.69	0.027	0.025	0.033	0.057	0.087	0.02
	Fluorene	ug/g	0.005	*	62	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050
	Indeno(1,2,3-cd)pyrene	ug/g	0.005	*	0.38	0.034	0.029	0.041	0.07	0.064	0.03
	1-Methylnaphthalene	ug/g	0.005	*	0.99	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050
	2-Methylnaphthalene	ug/g	0.005	*	0.99	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050
	Naphthalene	ug/g	0.005	0.6	0.6	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050
	Phenanthrene	ug/g	0.005	*	6.2	0.0074	0.0079	0.014	0.0095	0.02	<0.0050
	Pyrene	ug/g	0.005	*	78	0.025	0.021	0.026	0.049	0.074	0.016

***indicates no guideline available**

5 DISCUSSION

This discussion focusses on the performance results relative to stormwater management criteria and early results of the maintenance management program.

5.1 Stormwater Management Criteria

5.1.1 Resilience of stormwater infrastructure

Green infrastructure such as permeable pavement and bioswales can reduce flow frequency and rates. This is expected to reduce stress on elements of the downstream stormwater conveyance system which can provide total life cycle cost benefits. Although designed for moderate sized events, the detention storage provided by these systems can help to reduce peak flows during large events. This can reduce the frequency of surcharging in the downstream storm sewer.

The ability of the green street retrofit to reduce flow frequency was evident. Only 14 melt or precipitation events produced outflow during the study period. By contrast, the traditional grass swale produced outflow for 129 events, including many events smaller than 10 mm.

Eight events (summarized in **Table 4-6**) with magnitudes greater than 33 mm, occurred during the monitoring period. For the other large events, peak flows were reduced by at least 74 per cent at LV-4.

Use of green infrastructure provides resilience in the sense that the hydrologic response of a site with green infrastructure under the more frequent and intense events of the future may be similar to the hydrologic response of a site without green infrastructure to events typical of the past. Thus, retrofitting existing sites with green infrastructure may allow downstream stormwater systems to continue to function under future climate conditions.

5.1.2 Recharge

In some areas, recharge is important to sustain water supplies and baseflow to streams and wetlands. Baseflow is important to sustain the quantity of water between rainfall (and melt) events but also to regulate the thermal conditions in streams.

Substantive volume reductions were measured for both the conventional grass swale (68 per cent) and the green street (92 per cent). If the influent stormwater does not leave as measured outflow, it may be retained as “soil” moisture and ultimately be returned to the atmosphere. Or, it may bypass the underdrains and infiltrate into the native materials.

The green street design included a storage depth of 0.50 m below the invert of the underdrain. Water which was not intercepted by the underdrain and entered this storage layer had the opportunity to infiltrate into the native materials. Even where native materials have low permeability, a substantial depth can infiltrate over hours and days.

5.1.3 Erosion

The erosion control criterion is detention of 5 mm. The criterion has been met if it can be demonstrated that 5 mm can be retained (does not become outflow to storm sewers and downstream watercourses). **Table 3-3** estimated the volume produced by a 5 mm event on the contributing area to be 21 m^3. Water that reaches the storage below the underdrain can be considered to be retained. Although the estimated volume of this storage was only 8.2 m^3 (Table 3-3), the system was able to retain the full 5 mm volume and more. The smallest event to produce outflow from LV-4 was a 20 mm event (with an equivalent volume of 84 m^3) on April 19, 2015 when the antecedent conditions were quite wet.

This criterion should be applied to events that produce flows within receiving water courses that have the largest (cumulative) effects on channel erosion (mid to bankfull flows). For the eight events with magnitudes larger than 33 mm, summarized in **Table 4-6**, at least 30 mm were retained (i.e did not appear as measured outflow). If similar performance can be verified at a number of green infrastructure site, it should be possible to set the bar higher with respect to erosion control criteria.

5.1.4 Water Quality

All watercourses and water bodies within CVC's jurisdiction require, at a minimum, an enhanced level of protection (i.e. 80 per cent TSS removal). The green street retrofit achieved 93 per cent mass reduction of TSS. The traditional grass swales also reduced the outflow mass of TSS but the 72 per cent mass reduction measured falls short of the requirement for enhanced protection.

The green street also had good performance with respect to mass reduction of total phosphorous (83 per cent) and metals except nickel (>90 per cent). This provides evidence of the value of low impact development retrofits for areas where these parameters are of particular concern. The mass removal of dissolved nutrients was slightly lower, with percent mass removal of ortho-phosphate and nitrate estimated at 70 and 68 per cent, respectively, for LV-4. The green street out-performed the conventional grass swales, which had percent mass removals of 69 and 15 per cent for these same two constituents. The median effluent concentrations of nutrients for events which did produce outflow were higher than the conventional grass swale and curb and gutter control sites.

5.2 Maintenance and Life Cycle Costs

The bioswales at Lakeview are designed to trap debris, sediments and other stormwater pollutants. Over time these contaminants will accumulate and will require periodic removal through maintenance. Healthy vegetation is also important for aesthetics and optimal performance. All stormwater management systems require maintenance but less information is available on the necessary frequency of maintenance activities for low impact development systems, compared to stormwater ponds. Understanding the maintenance needs of these systems is a priority for the program and property owners. Reasonable maintenance requirements are essential for widespread implementation of these technologies.

Long term infrastructure assessment is needed (both quality and quantity performance) to capture when a decline in performance occurs and the extent to which performance is restored once maintenance work has been completed. Therefore maintenance documentation in concert with long term performance assessment is required in order to link maintenance activities to changes in performance. Some maintenance requirements may only be detectable through long term performance (i.e. filter media reaching saturation). This information in addition to cost tracking is valuable for asset management.

A maintenance checklist was developed to quantitatively record site conditions and maintenance needs as accurately as possible. The goal of the checklist format is to make inspections easy and straightforward for anyone to complete (**Figure 5-1**). There is a corresponding legend to accompany the checklist to give guidance to someone who may not be familiar with LID facilities. The same information is collected each time in the same format, improving consistency and making it easier to track changes over time (**Appendix E**). By reviewing the checklist data over time a person can determine the frequency of maintenance needed for each site and provide insight into future designs and planning of LID features. Developing a maintenance schedule based on data gathered at the site, allows for the establishment of maintenance costs, which are important to the functionality and life cycle of LID features. Results are discussed in Section 6.

Figure 5-1 CVC staff completing an LID inspection checklist at our Public Lands rain garden (left), CVC staff performing basic maintenance (right)

5.3 Maintenance Lessons Learned

The following section discusses some results from CVC's Maintenance Monitoring Program. Other information on maintenance to keep LID features functioning as designed can be found on TRCA's STEP website and in CVC's LID Certification Protocols: Bioretention Practices (2015).

5.3.1 Plant Selection

Plants should ideally be planted in the spring and fall when temperatures are cooler and rain is more frequent. In their first season of establishment they should be watered daily. This will help the roots grow and spread out throughout the filter media layer. Larger, more mature plants are usually less likely to die, but plugs will grow nicely if proper care is taken. It is also important to choose the right plants for the area and different factors should be considered while making this decision, such as the amount of sunlight, soil conditions, and aesthetics. It is good to have a variety of plants that will bloom throughout the season and offer different colours and textures for an interesting garden. The height of the plants is also important depending on location as they could result in a visual hazard if planted close to roads or driveways as visibility is reduced. For further information on plant selection and establishment refer to CVC's Landscape Design Guide for Low Impact Development (CVC, 2010), LID Certification Protocols: Bioretention Practices (CVC, 2015), and various factsheets and case studies that can be found on the website.

Figure 5-2: New plantings were just done in one of the bioswales at Lakeview. They will now require extra care and maintenance until they are established.

5.3.2 Inlet Maintenance

Since CVC began collecting maintenance data in September 2012, some reoccurring issues have been observed at Lakeview, such as debris blocking the inlets. This can negatively affect the performance of the bioswales if left unaddressed as water will be unable to enter the system resulting in by-pass.

- Large amounts of organic debris (such as leaves and pine cones) are present in the fall and can block inlets (**Figure 5-3**).

Figure 5-3 Leaves blocking the inlet and partially covering the bioswale, which could impede flow and reduce performance

5.3.3 Winter Maintenance

LID facility design should be planned carefully with consideration for the changing seasons and conditions. For example at Lakeview CVC has observed:

- Snow from the street is plowed and dumped into some of the bioretention cells which has caused damage to the overflow caps (**Figure 5-4**) as the weight of the snow and/or snow plows have cracked or removed them

Figure 5-4 Missing overflow cap at the outlet pipe in the Spring after the snow has melted

- Winter monitoring is important to ensure damage to the facility does not occur during City snow plow operations (**Figure 5-5**).

Figure 5-5 Street in Lakeview after being plowed by the City of Mississauga

5.2.2 Facility Monitoring

The inlets did not match design elevations at the grass surface, which prevented runoff from entering the facility (**Figure 5-6)**. To correct the issue, grading was lowered on the grass sections to match the design drawings (**Figure 5-7**). Further improvements, such as adding paved channels at the inlets to better direct the stormwater runoff into the bioswales, are being planned for the fall of 2016.

Figure 5-6: Inlet with incorrect grading, water is unable to enter the bioswale

Figure 5-7: Grading being corrected at the curb-cut inlets in Lakeview

6 DISCUSSION - MONITORING OBJECTIVE ASSESSMENT

The Lakeview monitoring program is supporting CVC's Monitoring Strategy objectives. The following summarizes progress against each objective from the strategy.

1. Evaluate how a site with multiple LID practices treats stormwater runoff and manages stormwater quality as a whole.
    - Three years of monitoring data has shown that the green street retrofit is achieving high mass load reduction for all parameters of concern. These results are attributed to the very high runoff volume reductions.
    - Water quality concentration results are generally below or equal to EMCs from NSQD land use database and are in a similar range to other infiltration BMPs in the BMPDB.
    - Water quality concentration results are generally below PWQO and CCME guidelines suggesting the discharge at the LID monitoring site may have a substantial positive affect on receiving water conditions including aquatic life.
2. Evaluate the long-term maintenance needs and maintenance programs and the impact of maintenance on performance.
    - Since July 2012, CVC monitoring staff collected data on maintenance activities performed and inspection conditions of the LID facilities on a biweekly basis. A site inspection checklist has been created and is used by staff during each site visit (**Appendix E**).
    - To date conclusions can be drawn on the importance of the selection and location of LID plantings. Both selection and location of plantings play a critical role in system appearance and can affect operating costs. The type and size of plants when commissioned is also a critical factor in plant success. Fall planting is preferred to summer planting. Spring planting is also acceptable if summer watering occurs.
    - Inlet maintenance has been identified as an ongoing issue as the grass at the inlet sometimes impedes the flow of stormwater, resulting in by-pass. This issue has been brought to the City's attention and will be addressed in the fall of 2016 by modifying the inlets with a concrete spillway.
    - There was a transfer of maintenance responsibility from the contractors to the homeowners after the second season of establishment. CVC is offering assistance in the form of guidance documents and events aimed at maintenance needs and requirements for the residents of Lakeview. This will ensure they have a proper understanding of not only how to perform proper maintenance, but the importance of maintenance in the long-term function of LID facilities.
3. Determine the life cycle costs for LID facilities
    - Pending further funding, CVC plans to continue to monitor the Lakeview site to assess the long term performance and maintenance requirements.
4. Assess the water quality and quantity performance of the LID facilities in clay or low infiltration soils and those that do not use infiltration.
    - Results for the 2012 to 2015 monitoring period show that the green street achieves a volume reduction of 92 per cent.
    - In 2014, more than 15 mm of precipitation was required to fill the storage below the underdrain at the monitoring location. Outflow was only generated for events with more than 30 mm of

precipitation during 2014. The underdrain may have conveyed water to locations with more storage capacity for events between 15 and 30 mm.

5. Evaluate whether the LID SWM systems are providing flood control, erosion control, water quality, recharge, and natural heritage protection as per the design standard.
   - The overall runoff volume reduction of 92 per cent contributes to all of these stormwater management objectives.
   - Performance has exceeded requirements for erosion control and water quality
   - Peak flow reductions, between 74 and 100 per cent were estimated for events with return periods between 2 and 10 years.

6. Assess the potential for groundwater contamination in the short and long term
   - This site is not within a wellhead protection zone, and given stakeholder priorities for the site and budget constraints this objective has not yet been evaluated at Lakeview. Refer to the IMAX Technical Monitoring Report for this objective.
7. Assess the performance of LID designs in reducing pollutants that are dissolved or not associated with suspended solids.
   - The mass removal of dissolved nutrients was slightly lower than other constituents, with percent mass removal of ortho-phosphate and nitrate estimated at 70 and 68 per cent, respectively, for LV-4. The green street out-performed the conventional grass swales, which had percent mass removals of 60 and 4 per cent for these same two constituents.
8. Demonstrate the degree to which LID mitigates urban thermal impacts on receiving waters.
   - This objective has not been evaluated at Lakeview. Refer to the *Elm Drive Technical Monitoring Report* for more information on this objective.
9. Assess the water quality and quantity performance of the LID technologies.
   - Refer to other objectives (e.g. 1, 5, 7).
10. Evaluate how SWM control ponds perform with LID upstream. Can the wet pond component be reduced or eliminated by meeting erosion and water quality objectives with LID.
    - This objective is not applicable to Lakeview.
11. Assess the potential for soil contamination for practices that infiltrate.
    - Long term soil sampling is needed to address this objective. This will be assessed with continued monitoring at Lakeview and will be reported on in a future report.
12. Evaluate effectiveness of soil amendments and increased topsoil depth for water balance and long-term reliability.
    - This objective is not applicable to Lakeview.
13. Evaluate and refine construction methods and practices for LID projects.
    - Lessons learned with respect to LID designs are being documented over the course of the monitoring program and will be used to update the CVC Design and Construction guidelines. Please refer to the Lakeview Case Study for more information.

14. Develop and calibrate event mean concentrations (EMCs) for various land uses and pollutants.
    - A good stormwater quality data set (50 sampled events) has been collected for a typical residential area of Mississauga with conventional stormwater conveyance systems as part of the Lakeview study.
15. Assess performance of measures to determine potential rebates on development charges, credits on municipal stormwater rates and/or reductions in flood insurance premiums.
    - Understanding the long-term performance potential for LID is important when developing rebate plans and offering credits. As mentioned for previous objectives, the Lakeview green street has demonstrated excellent water quantity and quality performance. CVC will continue to work with stakeholders to develop rebates and credit for LID.
16. Assess the ancillary benefits, or non-SWM benefits.
    - For the eight events with magnitudes larger than 33 mm, at LV-4, at least 30 mm were retained (i.e did not appear as measured outflow). If similar performance can be verified at a number of green infrastructure sites, it should be possible to set the bar higher with respect to erosion control criteria.
    - In some areas, recharge is important to sustain water supplies and baseflow to streams and wetlands. Baseflow is important to sustain the quantity of water between rainfall (and melt) events but also to regulate the thermal conditions in streams.
    - Please refer to CVC's Grey to Green: ROW Guide for direct benefits and www.bealeader.ca for indirect benefits, such as reduced erosion, street greening and improved fish health.
17. Assess the potential for groundwater mounding in localized areas.
    - This objective was not assessed for Lakeview.
18. Improve and refine the designs for individual LID practices.
    - LID landscapes should conform to typical urban landscaping principles, unlike stormwater ponds or stream restorations which follow natural landscaping approaches.
    - There are many options for design depending on the LID practice. Please refer to CVC's Grey to Green Road Retrofits: Road Right-of-Way and the Landscape Design Guide for Low Impact Development for a complete discussion of landscaping principles for successful LID design.
    - By monitoring the maintenance activities at Lakeview we are able to refine the designs based on location and scheduled maintenance needs as identified issues arise.
19. Assess the overall performance of LID technologies under winter conditions.
    - The water levels monitored at one location in the bioswale show that infiltration does occur through the filter media when the ground is partially or completely frozen.
    - Winter maintenance inspections are completed weekly to provide insight on how permeable pavement and LID features function differently than other surfaces such as asphalt. Inspections include completing a checklist and taking photographs and videos of snow accumulation and melt. Less road salt or other de-icer is needed for permeable pavement. Road salt tends to accumulate in the joints between pavers, showing that not as much salt is needed.

7 CONCLUSIONS

The Lakeview Green Street Retrofit demonstrated the use of LID within the municipal right-of-way. The green street retrofit included permeable pavement on the portion of driveways within the municipal right-of-way and bioswales. This report focused on analysis of monitoring data collected between 2012 and early July 2015.

The frequency of events of various sizes during the monitoring period was similar to the long-term frequency of occurrence. Events larger than 25 mm accounted for 32.5 per cent of the total precipitation and events larger than 30 mm accounted for 29 per cent of the total precipitation during the period of analysis. For the extreme event that occurred on July 8, 2013, a peak flow reduction of 25 per cent was estimated for the green street. For seven other events larger than 33 mm (estimated 2 yr return period), peak flow reductions ranging from 74 to 100 per cent were achieved by the green street. The runoff volume reduction achieved by the green street for events larger than 30 mm was 72.6 per cent, compared to only 45 per cent by the conventional grass swales. Lag times between peak rainfall and peak outflow from the systems was highly variable and strongly dependent on the rainfall distribution. These findings support the ability of LID systems to provide resilience. The peak flow reduction achieved by the detention storage of these systems can help to reduce the frequency of surcharging in the downstream storm sewer.

To reduce the erosive effects of stormwater runoff on receiving watercourses, CVC requires detention of 5 mm of rainfall. Retaining runoff on-site ensures that it will not contribute to downstream erosion. The smallest event to produce outflow from LV-4 was a 20 mm event on April 19, 2015 when the antecedent conditions were quite wet. This behavior was distinct from the conventional grass swale, which produced outflow for many events smaller than 10 mm and some events smaller than 5 mm. For the eight events with magnitudes larger than 33 mm, at least 30 mm were retained (i.e did not appear as measured outflow). If similar performance can be verified at a number of green infrastructure site, it should be possible to set the bar higher with respect to erosion control criteria.

Events up to 25 mm in magnitude occur much more frequently and contribute a large proportion of the average annual precipitation. Events in this size range are also responsible for transporting a large proportion of the annual contaminant mass delivered to receiving waters. Therefore, their management is particularly important for water balance and water quality objectives. The green street virtually eliminated outflow for events up to 25 mm in magnitude. The overall runoff volume reduction (for all events) achieved by the green street was 92 per cent, compared to only 68 per cent by the conventional grass swales.

All watercourses and water bodies within CVC's jurisdiction require, at a minimum, an enhanced level of protection (i.e. 80 per cent TSS removal). The green street retrofit achieved 93 per cent mass reduction of TSS. The traditional grass swales also reduced the outflow mass of TSS but the 75 per cent mass reduction measured falls short of the requirement for enhanced protection.The green street also had good performance with respect to mass reduction of total phosphorous (83 per cent) and metals except nickel (>90 per cent). This provides evidence of the value of low impact development retrofits for areas where these parameters are of particular concern. The mass removal of dissolved nutrients was slightly lower, with percent mass removal of ortho-phosphate and nitrate estimated at 70 and 68 per cent, respectively, for LV-4. The green street out-performed the conventional grass swales, which had percent mass removals of 60 and 4 per cent for these same two constituents.

The dataset of effluent concentrations is valuable for examining potential long-term effects on surface and groundwater, or alternatively potential benefits compared to other stormwater management systems. For surface waters, comparison to the Provincial Water Quality Objectives can flag potential concerns. Designs may be targeted to enhance removal of particular contaminants if there are specific concerns for a receiving water. An excellent runoff quality dataset (with 50 sampled events) has also been collected for a residential area in Mississauga, with conventional stormwater conveyance systems, Inspections have been carried to visually document performance and identify maintenance needs. Problems with the elevations of curb cuts were observed following construction. Removal of accumulated debris at inlets was identified as an important maintenance need. The ultimate goal is to continue monitoring long-term performance and maintenance needs for life-cycle cost assessment and asset management.

8 REFERENCES

Atkins. 2015. Flood Loss Avoidance Benefits of Green Infrastructure for Stormwater Management. Prepared for United States Environmental Protection Agency, December 2015. https://www.epa.gov/sites/production/files/2016-05/documents/flood-avoidance-green-infrastructure-12-14-2015.pdf

Bannerman, R.T., Dodds, R.B., Owens, D.W, Hughes, P.E., 1992, Source of pollutants in Wisconsin Stormwater: 1 for U.S. Environmental Protection Agency Region V: Wisconsin Department of Natural Resources Grant number C9995007-01 Canadian Construction Association (CCA), Canadian Public Works Association, Canadian Society for Civil Engineers and Federation of Canadian Municipalities. 2012. Municipal Roads and Water System. Volume 1. ISBN 978-1-897150-45-0

Canadian Infrastructure Report Card (CIRC). 2016. Informing the Future: The Canadian Infrastructure Report Card. www.canadainfrastructure.ca

Canadian Council of Ministers of the Environment. (CCME). 2014. Canadian Water Quality Guidelines for the Protection of Aquatic Life. http://www.ccme.ca/en/resources/canadian_environmental_quality_guidelines/

Centre for Watershed Protection. 2010. Stormwater Management Design Manual. New York State Department of Environmental Conservation. Albany New York

City of Mississauga. 2009. Strategic Plan: Our Future Mississauga. http://www.mississauga.ca/file/COM/StrategicPlan_Web_04_22_2009.pdf

City of Mississauga. 2010. Water Quality Strategy and Green Development Standards. http://www6.mississauga.ca/onlinemaps/planbldg/UrbanDesign/5-GDS-Standards-website.pdf

City of Mississauga. 2014. Asset Management Plan: Building, Stormwater & Linear Transportation. http://www7.mississauga.ca/documents/Finance/2014/Infrastructure_Sustainability.pdf

City of Mississauga. 2015. Winter Maintenance: Track Snow Plows and Salters Mississauga Roads App. http://www.mississauga.ca/portal/residents/snowclearingoperations?paf_gear_id=3700008&itemId=57900071&action=faqAnswer

Credit Valley Conservation. 2013. Grey to Green Streets - Implementing Site Level LID Retrofits within the Road. http://www.creditvalleyca.ca/wp-content/uploads/2013/09/SWI-ROWDraft-Complete1.pdf

Credit Valley Conservation. 2010. Landscape Design Guide for Low Impact Development. http://www.creditvalleyca.ca/wp-content/uploads/2012/02/cvc-lid-swm-guide-appendix-b.pdf

Credit Valley Conservation. 2015. Low Impact Development Certification Protocols: Bioretention Practices. http://www.creditvalleyca.ca/wp-content/uploads/2015/03/web-version-2015-03-20_DRAFTCVCbioretentionCertificationProtocols.pdf

Credit Valley Conservation. 2012. Stormwater Management Criteria.http://www.creditvalleyca.ca/wp-content/uploads/2012/09/CVC-SWM-Criteria-Appendices-August-2012.pdf

Credit Valley Conservation. 2012. Stormwater Management Monitoring Strategy Report. http://www.creditvalleyca.ca/wp-content/uploads/2012/11/SWMmonitoringStrategyDraft.pdf

Credit Valley Conservation. 2009. Water Quality Strategy.http://www.creditvalleyca.ca/wp-content/uploads/2011/07/Final-PII-WQSModelingReport.pdf

Davis, A.P., Hunt, W.F., Traver, R.G., Clar, M. 2009. Bioretention technology: overview of current practice and future needs. J. Environ. Eng. 135(3): 109-117

Environment Canada (EC). 2013. Quickfacts. Retrieved from http://www.ec.gc.ca/grandslacs-greatlakes/default.asp?lang=En&n=B4E65F6F-1 January 2014.

EPA. 2012. Maintenance of low impact development. http://water.epa.gov/polwaste/green/upload/bbfs6maintenance.pdf

Federation of Canadian Municipalities (FCM). 2007. Danger Ahead: The Coming Collapse of Canada's Municipal Infrastructure.

Federal Interagency Stream Restoration Working Group (FISRWG). 1998. Stream Corridor Restoration: Principles, Processes, and Practices. PB98-158348LUW.

Hood, M.J., Clausen J.C., Warner G.S. 2007. Comparison of stormwater lag times for low impact and traditional residential development. Journal of the American Water Resources Association. 43(4) 1036-1046.

ICF Marbek 2012. Low Impact Development Discussion Paper, November 2012.

Insurance Bureau of Canada (IBC). 2012. Water Damage is on the Rise: Are you Protected? http://www.ibc.ca/en/home_insurance/documents/brochures/water_damage_on_rise_en_web.pdf

Insurance Bureau of Canada (IBC). 2014. FACTS of the Property and Casualty Insurance Industry. 36th edition, ISSN 1197 3404.

Koval, Patricia. 2013. Climate Change Risk: Is Liability Lurking for Professional Engineers. Engineering Dimensions, January/February, 2013.

Lake Simcoe Region Conservation Authority. 2007. Lake Simcoe Basin Stormwater Management and Retrofit Opportunities 2007. http://www.lsrca.on.ca/pdf/reports/stormwater_retrofit.pdf

Lake Simcoe Region Conservation Authority. 2011. Stormwater Pond Maintenance and Anoxic Conditions Investigation Final Report. http://www.lsrca.on.ca/pdf/reports/stormwater_maintenance.pdf

Marbek (submitted to Ontario Ministry of Environment). 2010. Assessing the Economic Value of Protecting the Great Lakes: Rouge River Case Study for Nutrient Reduction and Nearshore Health Protection.http://www.greeninfrastructureontario.org/sites/greeninfrastructureontario.org/files/Final%20Rouge%20Report%20Nov%2030.pdf

Marbek (submitted to Conservation Ontario). 2012. Low Impact Development Discussion Paper, November 2012. http://www.creditvalleyca.ca/wp-content/uploads/2013/01/LID_DISCUSSION_PAPER_NOV_2012.pdf

Maunder, D. 2010. Why LID for the Public Realm? What are the obstacles, barriers, challenges, opportunities and benefits? The Proceedings of New Challenge: A Climate for Change 2010 CSA/CMHC/CVC LID Conference. September 28, 2010, Mississauga, ON., Canada.

NH DEP. 2008. New Hampshire Stormwater Manual. http://des.nh.gov/organization/divisions/water/stormwater/manual.htm

Ontario Ministry of Environment. (MOECC). 2012. Ministry of the Environment's Great Lakes Protection Strategy. http://www.ene.gov.on.ca/stdprodconsume/groups/lr/@ene/@resources/documents/resource/stdprod_096950.pdf

Ontario Ministry of Environment. (MOECC). 2003. Stormwater Management Planning and Design Manual. https://dr6j45jk9xcmk.cloudfront.net/documents/1757/195-stormwater-planning-and-design-en.pdf

Ontario Ministry of Environment. (MOECC). 1999. Water Management Policies, Guidelines, Provincial Water Quality Objectives of the Ministry of the Environment. July 1994, Reprinted February 1999.

http://www.ene.gov.on.ca/stdprodconsume/groups/lr/@ene/@resources/documents/resource/std01_079681.pdf

Ontario Ministry of Infrastructure. (MOI). 2006. ReNew Ontario: Progress report 2006. http://www.moi.gov.on.ca/pdf/en/renew2006/ReNewOntarioSummary.pdf

Ontario Ministry of Infrastructure. (MOI). 2013. Building together: Municipal infrastructure strategy. http://www.moi.gov.on.ca/en/infrastructure/building_together_mis/management.asp.

Personal Communication with Harold Reinthaler, Partner, Schaeffers & Associates, Ltd., Concord, Ontario. October 2012

Prince George's County, Maryland Department of Environmental Resources Programs and Planning Division. 1999. Low-Impact Development Hydrologic Analysis.

Royal Bank of Canada (RBC). 2013. 2013 RBC Canadian Water Attitudes Study. http://www.rbc.com/community-sustainability/_assets-custom/pdf/CWAS-2013-report.pdf

Scherer, G. 2007. Low impact development as a solution to the CSO problem in the NY-NJ harbor estuary. http://nynjbaykeeper.org/wp-content/uploads/2013/05/CSO-LID-FINALTEXT-11-7-07_andy.pdf

Schueler, T. 1995. Environmental Land Planning Series: Site Planning for Urban Stream Protection. Prepared by the Metropolitan Washington Council of Governments and the Center for Watershed Protection, Silver Spring, Maryland.

Schueler, T. 1987. Controlling Urban Runoff: A Practical Manual for Planning and Designing Urban BMPs. Metropolitan Washington Council of Governments, Washington, DC.

Toronto and Region Conservation. 2013. Assessment of life cycle costs for low impact development stormwater management practices. http://www.sustainabletechnologies.ca/wp/wp-content/uploads/2013/06/LID-LCC-final-2013.pdf

Toronto and Region Conservation Authority (TRCA). 2013. Toronto and Region Watersheds Report Card 2013. http://trca.on.ca/dotAsset/157180.pdf

TorStar Network. Mississauga News. Mississauga resident living in tent since flood. July 17, 2013. Available: http://www.mississauga.com/news-story/3895480-mississauga-resident-living-in-tent-since-flood/

United States Environmental Protection Agency (USEPA). 2003. Protecting Water Quality from Urban Runoff. EPA 841-F-03-003, Washington, DC.

United States Environmental Protection Agency (USEPA). 2007. Reducing stormwater costs through low impact development (LID) strategies and practices. EPA 841-F-07-006.

USGS. 2008. A Comparison of Runoff Quantity and Quality from Two Small Basins Undergoing Implementation of Conventional and Low-Impact-Development (LID) Strategies: Cross Plains, Wisconsin, Water Years 1999–2005. http://pubs.usgs.gov/sir/2008/5008/pdf/sir_2008-5008.pdf

Walsh, C.J., Roy, A.H., Feminella, J.W., Cottingham, P.D., Groffman, P.M., Morgan, R.P. II. 2005. The urban stream syndrome: Current knowledge and the search for a cure. Journal of the North American Benthological Society 24(3):706-723.

LAKEVIEW, CITY OF MISSISSAUGA

LOW IMPACT DEVELOPMENT INFRASTRUCTURE PERFORMANCE AND RISK MANAGEMENT ASSESSMENT

Appendix A

Public Lands Monitoring Plan

NOTICE

DRAFT REPORT

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1 INTRODUCTION

Public lands constitute a significant portion of municipal land use areas and hold much of the green space in our communities. These spaces are ideal for implementing green infrastructure projects like bioretention units or rain gardens. Using the principles of low impact development (LID) to re-establish natural processes, public land sites can help to reverse the impacts of urban development. Small changes made on multiple sites throughout a watershed can add up to significant impacts. These changes ensure water resources remain drinkable, swimmable and fishable for future generations.

Bioretention units are vegetated practices that detain, filter and infiltrate stormwater runoff. The most important component of these practices is the bioretention soil media. Bioretention soil media is made using specific ratios of sand, fine soils and organic material to achieve an optimal balance of subsurface storage, filtration, pollutant removal and plant growth. Bioretention practices can be integrated into a diverse range of landscapes, including 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 as these surfaces generate large amounts of runoff that can be intercepted and treated by these features. Bioretention maintenance requirements are similar to those of other landscaped areas and include trash removal, weeding, replacement of dead vegetation, and checking for clogging of inlets and outlets. The amount of effort requirement to maintain this type of practice will vary based upon the type of vegetation and landscape design. The choice of selecting grasses or other plants for a particular bioretention practice should be based on several factors including aesthetics, maintenance requirements, and climate. In general, planted bioretention features requiring a higher degree of maintenance are recommended for higher profile settings where sufficient resources can be dedicated to maintaining a high degree of visual appeal. This can help to build community support and achieve buy-in, so long as regular maintenance is conducted. For more information on LID plantings, please refer to CVC's *Landscape Design Guide for Low Impact Development*.

The Public Lands monitoring program is comprised of eight different LID sites within the Credit Valley watershed that are all located within the City of Mississauga, with the exception of the Terra Cotta Conservation Area, which is located in the Upper Credit Watershed in the Town of Caledon. These sites vary in terms of both design and implementation as some sites were retrofits that had to accommodate existing onsite conditions, while other LID features were incorporated as part of a new site development. In the latter case the LID practices could customized and designed in conjunction with the rest of their respective project sites.

This monitoring program aims to monitor the subsurface water level to track stormwater infiltration and storage in the LID feature (bioretention unit or rain garden). This will help to understand how the feature functions as they are all unique, using different LID designs to facilitate in infiltration. Different soil mixes and design features were used at various locations, and this data will be important in determining whether specific design features enhance performance, and what the relative impact of maintenance activities are over time.

1.1 Low Impact Development Features and Site Designs

Table 1-1 provides an overview of the various Public Lands sites and summarizes the key differences in each LID feature's characteristics. Although some sites incorporated multiple LID features (e.g. permeable pavements in addition to bioretention features or rain gardens), the monitoring of water level is only occurring in the bioretention and rain garden units. Maintenance inspection logs are going to be completed for both the bioretention and permeable paver sections of each site. A limited number of LID features located on some of the Public Lands sites (the green roof at Lakeside Park, for example) is not going to be monitored in any way by CVC. For an in-depth discussion of each site and an overview of its LID features and site design, refer to the individual site case studies that can be found on CVC's LID website: *creditvalleyca.ca/low-impact-development*

Table 1-1 Public Lands LID Site Summary

Site Location	Type of Public Land Site	LID Features on Site	Primary Drainage Area Inlet to LID Features	Soil and drainage materials	Underdrain Present?	Outlet to municipal Storm Sewer?
O'Connor Park	Municipal Park	• Permeable pavers • Bioretention cell • Infiltration trenches	Parking lot	• Bioretention filter media • Clearstone • Pea gravel	Yes	No
Lakeside Park	Municipal Park	• Bioretention cell • Green Roof • Pervious concrete parking lot • Reclaimed water pond and irrigation system	Parking lot	• Bioretention filter media • Clearstone	Yes	No
Green Glade P.S.	Senior Public School	• Rain Garden	Parking lot and roof runoff	• Bioretention filter media	No	No
Lakeview Neighbourhood	Residenti al road-right-of-way	• Permeable pavers • Bioretention cells	Residentia l Road and Driveways	• Bioretention filter media • Angular clearstone • Angular chipstone	Yes	Yes
Unitarian Church	Place of Worship	• Rain Garden	Parking lot	• Amended native soil	No	Yes
Elm Drive Adult Education Center	Adult Educatio n School	• Permeable pavers • Bioretention cells	Road	• Angular clearstone • Sand • Bioretentio n filter media	Yes	Yes
Portico Church	Place of Worship	• Bioretention cell	Parking lot	• Bioretention filter media • Clearstone	Yes	Yes
Terra Cotta Conservation Area	CVC Conserva tion Area	• Rain Garden	Roof runoff	• Amended native soil	No	No

2 MONITORING PURPOSE AND OBJECTIVES

2.1 Purpose

The purpose of this study is to quantify the rate at which different infiltration practices (i.e. rain gardens and bioretention units) are able to absorb and infiltrate stormwater on-site on a year-round basis. Each LID feature has a unique design, so infiltration rates are expected to vary accordingly. In light of this, it is important to understand how much of an impact – if any – specific design features have on overall performance. The evaluation of functionality will focus on water quantity and maintenance aspects from the spring of 2012 onward, based on available funding.

2.2 Goals and Objectives

The ***monitoring objectives*** are as follows:

1. Determine the infiltration rates of the LID features by measuring the subsurface water levels within each practice
2. Evaluate whether the LID features are functioning as designed, or if modifications are required
3. Evaluate long-term maintenance needs and maintenance programs, and the impact that maintenance has on performance
4. Determine the life cycle costs for the LID practices based on the site conditions and maintenance performed

3 PROJECT SCHEDULE

1. Development of Site Inspection Log for Maintenance Tracking – Spring 2012
2. Installation of observation wells and monitoring equipment – Spring 2012
3. Perform soil sampling – Spring 2012
4. Development of individual site Case Studies – Fall 2012
5. Compile and analyse data from first monitoring year – Winter 2013
6. Compile and analyse data from second monitoring year – Winter 2014
7. Compile and analyse data from third monitoring year – Winter 2015
8. Complete cost analysis of maintenance tasks performed and site conditions – Spring 2016
9. Complete analysis and reporting for all sites – Spring 2016
10. Final data analysis– TBD

4 STUDY AREA

4.1 Site Locations

There are eight Public Lands sites throughout the CVC watershed that are being monitored in this program. They are all within the City of Mississauga with the exception of the Terra Cotta site, which is in the Town of Halton Hills.

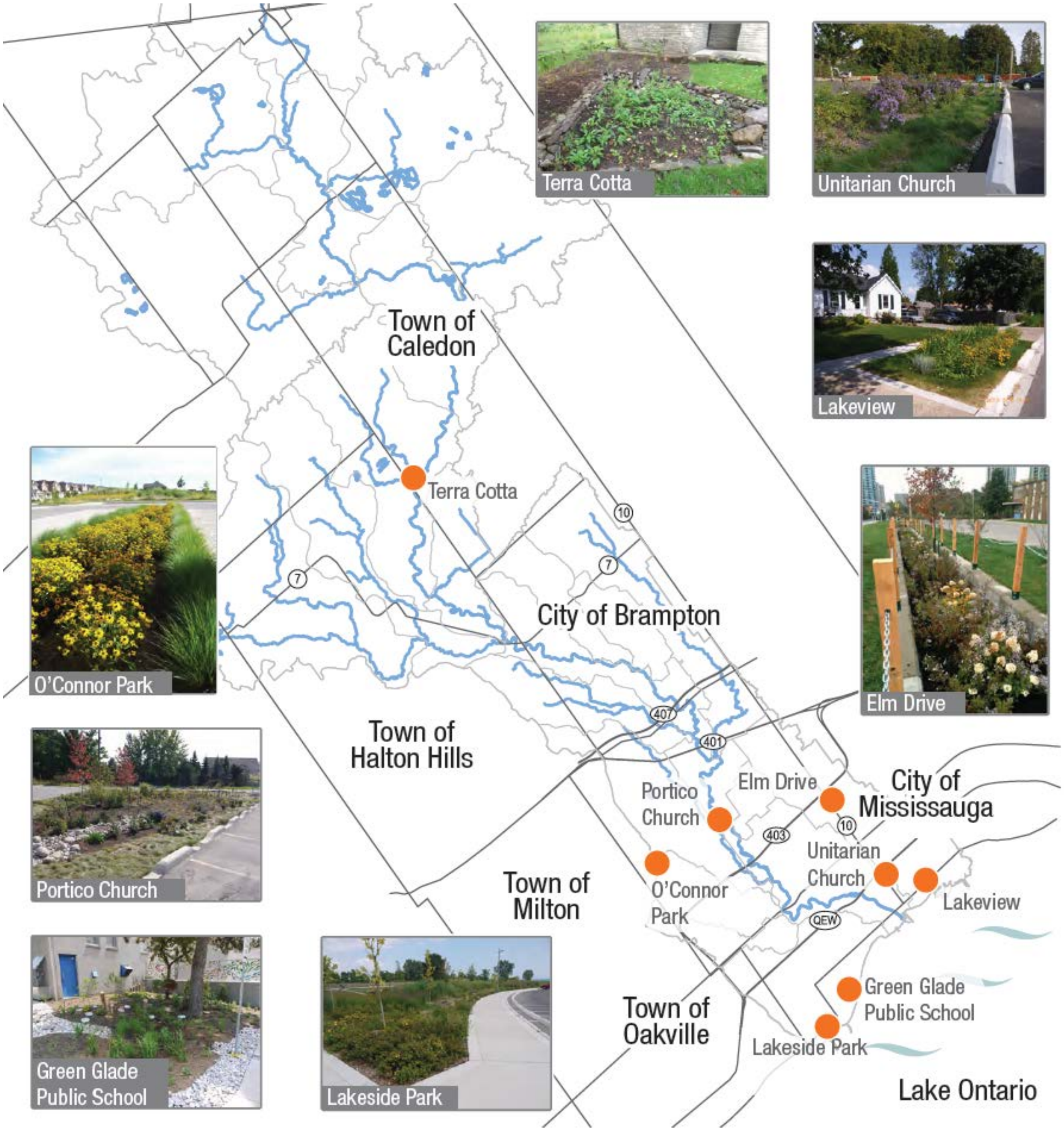

Figure 4-1 Public Lands monitoring locations

4.2 Monitoring Locations – Equipment Selection and Placement

Areas selected for monitoring equipment placement should be the lowest-lying areas within the bioretention or raingarden practice, as it is these locations where water is likely pond and where the soils will be most saturated. Deep wells monitoring infiltration rates can be installed either during facility construction or after construction is complete. It is preferable to install deep wells during construction if at all possible as this approach is less intrusive to the facility and allows for deeper placement. A standard piezometer is used, with a metal well casing on the outside to prevent theft and vandalism. The piezometer is buried, and for the ease of monitoring purposes the well casing should be level with the finished facility grade. This allows for more accurate manual measurements - to both compensate the logger data and confirm the sensor's accuracy.

In addition to level loggers, a barometric pressure transducer is required to compensate the raw data in order to provide an accurate measurement of water level. If multiple sites are being monitored, one barometric pressure transducer can be used for compensation across several locations, so long as the sites themselves are within a few kilometers of each other. Three barometric pressure loggers installed as part of the Public Lands monitoring initiative: one each at Terra Cotta, Elm Drive, and Lakeview. This is considered to provide sufficient coverage of the entire monitoring area, and will help to ensure each water level logger is within a reasonable proximity to one of the barometric pressure loggers.

5 WORK PLAN

This work plan lists the objectives of the program and provides the details on how and where these objectives will be met. The overall length of the program will be based on future funding.

Table 5-1 Project Work Plan

Objective	Location(s)	What will be monitored	Frequency	Equipment (How)
1. Determine the infiltration rates of the LID features by measuring the subsurface water level	Various City of Mississauga rain gauges and two CVC owned rain gauges	Meteorological station for background environmental data • Precipitation • Air temperature	• Continuous precipitation and air temperature data downloaded at **10** min intervals	• Heated rain gauge
	All monitoring sites, Subsurface water level	Level of the ground surface in relation to the well bottom to determine when/if surface ponding is occurring and drawdown rates over time.	• Continuous logging at **10** minute intervals • Site visits monthly for download	• One Hobo water level logger per site • Level tape to calibrate levels
2. Evaluate whether the LID features are functioning as designed and if modifications are required	All monitoring sites, As-built survey and subsurface water level	Level of the ground surface in relation to the well bottom to determine when/if surface ponding is occurring and drawdown rates. Crosscheck monitoring observation with as-built survey to ensure proper functionality.	• Initially review the as-built survey to see if features were constructed as designed, make modifications if needed • Review monitored water level in relation to different features (i.e. inlet and overflow outlet) to see if they are used and the frequency/functionality	• External consultant to complete as-built survey • Water level and meteorological monitoring equipment listed above
3. Evaluate long-term maintenance needs and maintenance programs, and the impact of maintenance on performance.	All monitoring sites, Drainage areas, inlets, outlets, facilities, etc.	• Site conditions • Maintenance needs, tasks and costs	• Each site visit or when maintenance is completed • Fill out inspection log monthly • Annual interviews with property managers	• Inspection log and legend • Camera
4. Determine the life-cycle costs for the LID practices.	Overall project	Track costs throughout life-cycle: • Design • Pre-construction • Construction • Maintenance and materials • Rehabilitation • Disposal	As needed throughout the duration of monitoring. Expected costs outside of the monitoring timeframe will be estimated using the TRCA life cycle assessment tool.	• Staff time

6 OVERVIEW OF MONITORING COMPONENTS

6.1 Subsurface Water Level Monitoring and Site Visit Activities

All sites will be visited monthly as the water level loggers to be used in this monitoring program are low-maintenance and do not require frequent downloading. This is an ideal site visitation interval which allows CVC staff to collect data in a timely manner, as well as track site conditions via a regular inspection interval.

In order to download the loggers in the field a laptop and the appropriate software is needed, in addition to all requisite connection cables. Connecting to the loggers and downloading data is a relatively simple process which requires little time to complete, and can be done year-round. A water level tape is also required as manual water level measurements are needed to compensate the water level data. It is also important to have a reference point (datum), so the water level tape is used to ensure that the loggers are taking accurate level measurements. If the loggers are found to be losing their accuracy, the reference datum and water level tape can be used as a calibration aid.

Tasks that occur during a regular field visit include:

- Opening the well and taking a water level measurement
- Removing the logger from the well in order to download the data
- Replacing the logger in the well and securing the well casing to protect against theft or vandalism
- Taking photos and documenting any changes that might have occurred onsite since the last visit
- Taking detailed notes of measurements, downloads, logger information, and site information
- Completing an inspection log for the visit, which includes recording the current site conditions and any maintenance needs

6.2 Meteorological Monitoring

A City of Mississauga rain gauge, located less than one kilometer from O'Connor Park, Lakeside Park, Green Glade P.S., Lakeview, Portico Church and Unitarian Church, will be used for the collection of precipitation data for the aforementioned locations. Field data will be recorded by the loggers and rain gauge at ten minute intervals. Data from the gauge will be compared to other nearby gauges for QA/QC purposes.

Both Elm Drive and Terra Cotta will use precipitation data recorded by a CVC-owned rain gauge. Data will be recorded and analyzed using a ten minute interval format, as above. Data from the gauge will be compared to other nearby gauges for QA/QC purposes.

6.3 Maintenance Inspections and Records

Long-term infrastructure performance assessment is needed to capture when a decline in performance occurs and how performance is restored after maintenance or remedial works have been completed. Maintenance documentation - in concert with long-term performance assessment - is therefore required in order to link maintenance activities to changes in performance when compared to design criteria. Some maintenance requirements may only be detectable through long-term performance (i.e. filter media reaching pollutant saturation). This information, in addition to tracking the associated costs, will support effective asset management.

An inspection log format will be used to record site conditions and maintenance needs throughout the monitoring program. The inspection log records information such as plant health, weed cover, inlet blockage, overflow blockage, litter and debris cover, etc. The same information will be collected during each monthly visit in a consistent format, thus ensuring the proper documentation of condition assessment data. This will allow for streamlined analysis of the inspection data and will make it easier to track changes over time.

In order to document maintenance activities and their associated costs, CVC staff will evaluate and note maintenance needs during site visits and coordinate with those responsible for performing maintenance. CVC staff will follow up with those responsible to gather records related to both the activities and their costs. CVC staff will interview property managers annually to collect maintenance records, costs and other related information on recurring maintenance issues. **Table 6-1** outlines the types of information that will be collected and the frequency.

Table 6-1 Summary of Proposed Inspection Activities and Timing

Activity	When to be Completed
Take photos from reference locations at the site.	When an inspection checklist is completed and before and after maintenance.
Keep logs of site visits, inspections and maintenance dates, activities performed, observations and associated costs.	Each visit or when maintenance is performed.
Look for common issues and maintenance tasks associated with LID such as trash accumulation, sediment deposition, erosion, and vegetation health to watch for changes over time.	Each visit
Inspect different areas of the LID feature such as the drainage area, inlets, outlets, and vegetation, to ensure nothing is overlooked and that the site can perform optimally.	When an inspection list is completed.
Outline any maintenance issues that need to be addressed and whether they are urgent or routine so that the appropriate actions can take place.	When an inspection list is completed.

6.4 Infiltration Testing

Infiltration testing will be conducted at each site within the bioretention facility once after construction is complete to ensure the facility passes the designed infiltration drawdown volume prior to assumption by the property owner. A Guelph Permeameter will be used for infiltration testing.

6.5 Soil Sampling

Soil sampling will be conducted at each site within the bioretention facility once after construction is complete to ensure the facility passes the design specifications to determine grain size and to ensure that the proper soil mixture was used. Some monitoring sites will be excavated during construction and filled with special engineered filter media mix, which is a blend of sand, organic debris, and fines. LID practices located at other sites will utilize the native soils in these locations, and will amend them with additional sand and compost to increase their porosity, infiltration and pollutant adsorption capacity. Collecting soil samples will be crucial in determining whether the soils meet design specifications and if the sites are constructed as intended.

6.6 Qualitative Observations

Throughout the monitoring program, photos will be taken at consistent locations at regular intervals to track seasonal and long-term variations.

Furthermore, CVC staff will visit the various sites throughout the monitoring program during a variety of precipitation events in order to record videos of flows going both into and out of the LID features.

This type of information will provide insight into the functionality of the system during variously-sized rainfall/runoff events.

7 DATA MANAGEMENT AND ANALYSIS

Data from all loggers at all locations will be downloaded once every month. Any issues encountered will be dealt with in a timely manner in order to avoid any loss of sensor data or other records. Initial reviews of the data will be conducted using logger software in the field, while more detailed reviews and QA/QC will be conducted in the office at a minimum of once per month.

Microsoft Excel is the primary tool used for the water level data analysis for this project. Due to the large dataset being generated, data is split into a number of different spreadsheet files to perform statistical analyses and calculations. A master spreadsheet is used to compile data and ensure that data is not lost when transferring it between users and spreadsheets.

The inspection logs that are filled out in the field will then be entered into a Microsoft Access database in order to be analysed more easily. The database will allow all of the information to be centrally kept, but permits quick manipulation of the data. It will also help with the tracking of site conditions over time.

Results will be used to complete a technical report outlining the performance compared to the project objectives. This will be posted on the CVC website for the public to access. Monitoring results will help to inform the future design and maintenance needs of different LID features.

LAKEVIEW, CITY OF MISSISSAUGA

LOW IMPACT DEVELOPMENT INFRASTRUCTURE PERFORMANCE AND RISK MANAGEMENT ASSESSMENT

Appendix B

Infrastructure Performance and Risk Assessment Protocol

NOTICE

The contents of this report do not necessarily represent the policies of the supporting agencies. Although every reasonable effort has been made to ensure the integrity of the report, the supporting agencies do not make any warranty or representation, expressed or implied, with respect to the accuracy or completeness of the information contained herein. Mention of trade names or commercial products does not constitute endorsement or recommendation of those products.

DRAFT REPORT

1 SITE DESIGN AND PHYSICAL LAYOUT

During construction a manhole was installed downstream for monitoring purposes at all Lakeview sites. Since the manholes are downstream of the facilities, they are ideally located to characterize the overall performance of each site in terms of the quantity of runoff produced from monitored precipitation events and to characterize the effluent water quality from the overall system. The drainage area contributing runoff to the manhole can be determined through analysis of aerial images, topography and on-the-ground surveying. Proposed design drawings have been included at the end of this appendix.

Monitoring peak flow will help CVC assess whether bioswales and permeable pavement at Lakeview are a viable method of adding resilience to urbanized areas where little stormwater management control currently exist.

2 INFRASTRUCTURE PERFORMANCE AND RISK ASSESSMENT PROTOCOL

This section of the document presents the monitoring protocol prepared by CVC. The section also includes information relevant to potential monitoring refinements on the site. This section of the report will evolve as monitoring methods are refined.

2.1 Hydrology

Weirs have been installed in the manholes downstream of each site. The weirs are custom compound weirs by Thompson Flow Investigations. The lowest measurable flow is 0.021 L/s[1] at LV-1 and LV-2 and 0.008 L/s[1] at LV-3 and LV-4. According to the manufacturer, the weirs do not need still water upstream (as it is not a sharp lip weir), and the level logger can be mounted close to weir, because it has been tested/calibrated to do so. An ISCO 4150 flow meter (or HACH FL901) has been installed in the monitoring manholes with the probe secured to the bottom of the manhole, upstream of the weir to ensure accurate water level measurements. The flow meter records water levels at 10-minute intervals (5-minute intervals at LV-1). The monitoring stations (excluding LV-3) are equipped with an ISCO 6712 automatic sampler for collection of water quality samples. The automatic sampler is set to trigger based on water level measured at the monitoring station (water elevation relative to the weir notch is used to determine flow). A heated tipping bucket rain gauge near the Lakeview sites (Mississauga Rain Gauge Network - S01 Third St.) provides the site precipitation data. The rain gauge is located on the roof of the Third St. fire station so the likelihood that the gauge will be subjected to higher winds during more severe storm events is higher. This could potentially cause the rain gauge to “undercatch” rainfall. Precipitation data collected during more severe storm events will be more closely examined for accuracy. A precipitation event is considered to occur when 2 mm or more precipitation is recorded. If more than 6 hours elapse between precipitation events, they are considered to be separate events.

[1] It is critical to recognize that there are many potential sources of uncertainty in flow measurement, even when a weir is properly installed, including the accuracy of the water level measurements (not a still water surface), debris effects, poor instrument accuracy for lower range of flows and other factors. Uncertainty in the range of 20% would not be unusual for measurement of stormwater runoff flow rate in the field using a weir. Volume measurements/estimates would likely be less accurate because of greater inaccuracy at low flows on the extended, declining limb of the hydrograph.

Figure 2-1: Flow Logger and Compound Weir

Figure 2-2: Level Probe Fastened to Weir Face

2.2 Surface Water Quality

CVC's surface water quality sampling goal is to sample a minimum of 10 precipitation events per year from each monitoring location with an ISCO 6712 automatic sampler. The sampler is connected to the water flow logger and triggered when the flow logger records a predetermined water level. A temperature logger was installed in each manhole to collect water temperature measurements from the BMP outflow. Pending funding, CVC would like to continue monitoring beyond 2016 to address long term objectives related to maintaining performance and maintenance needs.

The automatic sampler is programmed to collect samples that will allow for a composite sample to be compiled for water quality analysis for each event at the outflow monitoring station. The sampler holds 24 1-litre bottles. When the sampler is triggered, all bottles are filled provided there is sufficient runoff. Bottles that were sampled while outflow was observed are used to generate a flow-weighted composite sample. Currently the sampler is programmed to collect samples at a fixed time interval. The length of time between bottle fills may be lengthened or reduced depending on the event forecasted. This will either shorten or lengthen the sampling program in order to provide a flow-weighted composite sample that is representative of the event and that provides adequate sample volume to perform laboratory analyses. CVC has developed program lengths of 6, 12, 18, and 24 hours, with associated sample collection intervals of 10, 20, 30, and 40 minutes, respectively. Depending on the expected duration of the storm event forecasted, this program length is adjusted to collect samples over the entire storm hydrograph. Once the sample program is completed, CVC staff download data and create a flow-weighted composite sample for EMC analysis.

Figure 2-3: Water Quality Sampling

Samples are analyzed for:

- Chloride
- Turbidity
- Conductivity
- pH
- Total Suspended Solids (TSS)
- Total Dissolved Solids (TDS)
- Nutrients:
    - Total Phosphorus
    - Orthophosphate
    - Total Kjehldahl Nitrogen (TKN)
    - Total Ammonia
    - Nitrate & Nitrite
- Total Metals (Cadmium, Total Chromium Copper, Iron, Lead, Nickel and Zinc)
- Polycyclic Aromatic Hydrocarbons (PAH's) –These parameters have been discontinued due to low levels and many non-detects.
- E. coli--Sample hold times make this parameter infeasible to sample using automated equipment without refrigeration. If sampling for E. coli is conducted in the future, it would be appropriate to collect first flush samples. This would require babysitting samplers or manual sampling and quick transport of iced samples to laboratory.
- Oil & Grease--This parameter is being discontinued due to low levels and many non-detects as well as difficulties with creating a representative composite with immiscible material. A sample may be analyzed for Oil and Grease if a visual sheen is noted. The likely reason for this phenomenon is the result of sampling only effluent from this monitoring location. There may be high concentrations in the inflow, but none are detected in the effluent. It may be worth visually quantifying Oil and Grease levels of the inflow during the onset of a storm event to characterize this performance.

All water quality samples are brought to an accredited Canadian Laboratory, Maxxam Analytics in Mississauga (which has received accreditation from Standards Council of Canada for all water quality parameters of interest), for laboratory analysis. Table 2-1 summarizes water quality parameters, analytical methods and associated method detection limits (MDLs).

Figure 2-4: Typical sampling turbidity at LV- 1 (Control Site)

Figure 2-5: Typical sampling turbidity at LV- 2 (Grass Swales)

Table 2-1: Quality Parameters of Interest[1], Analytical Methods & Method Detection Limits (MDLs)

Water Quality Parameter	Units	Analytical Method	MDL[2]
Total Cadmium (Cd)	ug/L	EPA 6020	0.01
Total Copper (Cu)	ug/L	EPA 6020	0.1
Total Iron (Fe)	ug/L	EPA 6020	5
Total Lead (Pb)	ug/L	EPA 6020	0.05
Total Nickel (Ni)	ug/L	EPA 6020	0.1
Total Zinc (Zn)	ug/L	EPA 6020	0.5
Dissolved Chloride (Cl)	mg/L	EPA 325.2	1
Nitrate (NO_3)	mg/L	SM 4500 NO3I/NO2B	0.1
Total Kjeldahl Nitrogen (TKN)	mg/L	EPA 351.2 Rev 2	0.1
Orthophosphate (PO_4)	mg/L	APHA 4500 P-G	0.002-0.004[4]
Total Phosphorus (TP)	mg/L	SM 4500 P,B,F	0.002-0.004[4]
Escherichia coli (E. coli)[3]	CFU/100mL	MOE LSB E3371	10
Total Suspended Solids (TSS)	mg/L	SM 2540D	1

1The water quality parameters listed are recommended parameters of interest; CVC has performed a broad screening of over 27 parameters.

2Method detection limit is sometimes lower than the sample detection limit due to available sample volume and laboratory interferences.

3Monitoring of parameter may not be feasible using automated sampling and/or composite sampling techniques due to hold time constraints

4 Laboratory MD values ranged throughout the monitoring period

2.3 Surface Water Infiltration

A piezometer was installed downstream of LV-3 and LV-4 near the monitoring location. HOBO U20 water level loggers have been installed in the piezometers to measure water levels. An additional logger has been installed at a nearby location to record barometric pressure that will allow for level measurements to be compensated accordingly. All level loggers have been set to record at 10-minute intervals. Water level readings will be compared to precipitation amounts to estimate surface water infiltration in the bioretention cells. In addition, it is possible to estimate the drawdown time for stormwater to fully infiltrate into the bioretention cells.

Figure 2-6: Manual level measurements to verify accuracy of readings and to calibrate level logger as needed

2.4 Soil Sampling

The LID approach at Lakeview aims to minimize runoff and pollutants though the combination of permeable pavement and bioretention cells. Bioretention cells use plants and engineered filter media to chemically, physically and biologically treat pollutants. Soil sampling will help track contaminants and aid in evaluating the frequency of maintenance activities such as filter media replacement.

Soil sampling occurred in the bioretention units that receive runoff from the LV-4 catchment area. Sampling occurred October 9, 2014 after summer precipitation events but prior to the ground freezing. Soil (filter media) sampling was conducted at two depths. Samples were analyzed by Maxxam Analytics for inorganics, metals and polyaromatic hydrocarbons (PAHs).

Two composite soil samples were collected from three bioretention cells (six samples total). The shallow and deep samples were collected at approximately 5 cm and 30 cm below the filter media surface, respectively. In the sampled cells, three subsamples from each depth were combined to produce one composite sample. Comparison between two sampling depths provides information regarding the depth at which pollutant removal occurs for different parameters. In addition, sampling at two depths helps determine whether or not pollutants are migrating through the soil column over time. Collecting samples from multiple bioretention cells will provide insight on pollutant removal for different plant combinations and how parameter concentrations vary depending bioretention cell location (i.e different water volume inputs and sources depending on the cell). Moving forward soil sampling for contaminant tracking will occur biennially. The next soil sampling event for Lakeview is scheduled for Fall 2016.

Soil quality results were compared to CCME Soil Quality Guidelines for the Protection of Environmental and Human Health (CCME, 2014) and to the Environmental Protection Act, Ontario Reg. 153/04 Table 7: Generic Site Condition Standards for Shallow Soils in a Non-Potable Ground Water Condition Soil - Coarse Texture (MOE, 2011) for the appropriate land use.

2.5 Site Visits

CVC staff visit the sites at least once every other week to check battery power, inspect equipment, and make sure the site is operating properly. Data is downloaded either remotely or in person from each piece of equipment bi-weekly (or more frequently) using ISCO Flowlink 5, Flo-Ware, or Hoboware. The software will automatically summarize and plot the data graphically, which can then easily be exported to a program like Microsoft Excel. During site visits, CVC staff also note any changes that have occurred on the site, any equipment adjustments/maintenance, LID maintenance activities that have occurred and any other unusual or changed circumstances at the site. Water level probe calibration is checked and adjusted as needed during each field visit.

2.6 Site Maintenance

The stormwater facilities at Lakeview are designed to trap pollutants, and assuming the permeable pavement and rain gardens are effective, pollutants including trash/gross solids, sediments and other stormwater pollutants will accumulate that will need to be removed periodically through maintenance. Understanding maintenance needs of these systems is a priority for property owners to assess if these technologies are feasible from a City-wide perspective. The City of Mississauga and the Lakeview residents are responsible for the maintenance of this site. CVC monitoring staff complete inspection checklists during routine site visits documenting information such as trash/debris accumulation, inlet/outlet conditions, vegetation conditions etc. Separate winter maintenance inspections are also conducted to document snow/ice cover, road salt use, and general site conditions. Although this information is being collected now, meaningful interpretation can only be made with additional years of monitoring. A description of typical maintenance procedures is included in **Appendix D.** Provided funding is available, CVC plans to continue this initiative beyond 2016.

Long term infrastructure assessment is needed (both quality and quantity performance) to capture when a drop in performance occurs and how performance is restored once maintenance work has been done. Therefore maintenance documentation in concert with long term performance assessment is required in order to link maintenance activities to changes in performance. Some maintenance requirements may only be detectable through long term performance (i.e. filter media reaching saturation). This information in concert with cost tracking will benefit asset management information.

MISSISSAUGA
Leading today for tomorrow

FIRST STREET & THIRD STREET RECONSTRUCTION

CONTRACT No: 17 111 10128

Drawing Index

Description	Drawing No.
PLAN AND PROFILE – 1 (1ST STREET)	PP–1
PLAN AND PROFILE – 3 (3RD STREET)	PP–2
PARKETTE PLAN – 3 (3RD STREET)	PP–3
CROSS SECTIONS – 1 (1ST STREET)	CS–1
CROSS SECTIONS – 2 (3RD STREET)	CS–2
DETAILS	SD–1
PERMEABLE PAVEMENT DETAILS	PD–1
BIO–SWALE DETAILS	BS–1
BIO–SWALE DETAILS	BS–2
FRENCH DRAIN PLAN	FD–1
DRIVEWAY DETAILS – 1 (1ST STREET)	DE–1
DRIVEWAY DETAILS – 2 (3RD STREET)	DE–2

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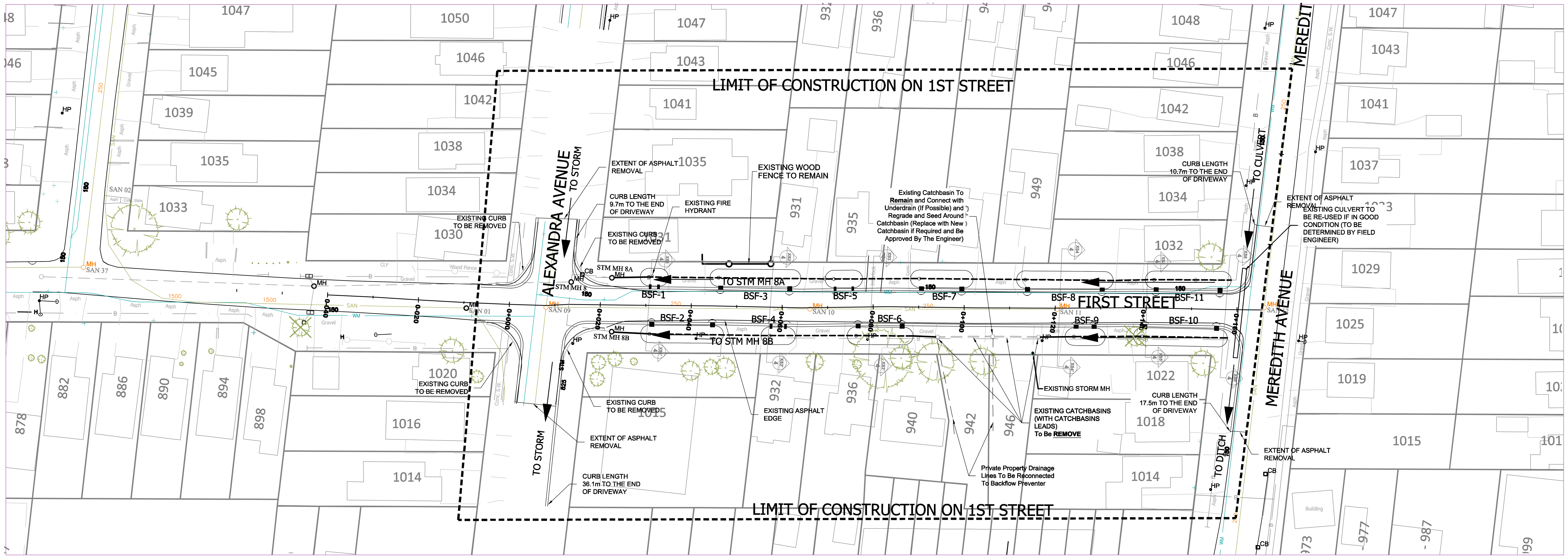
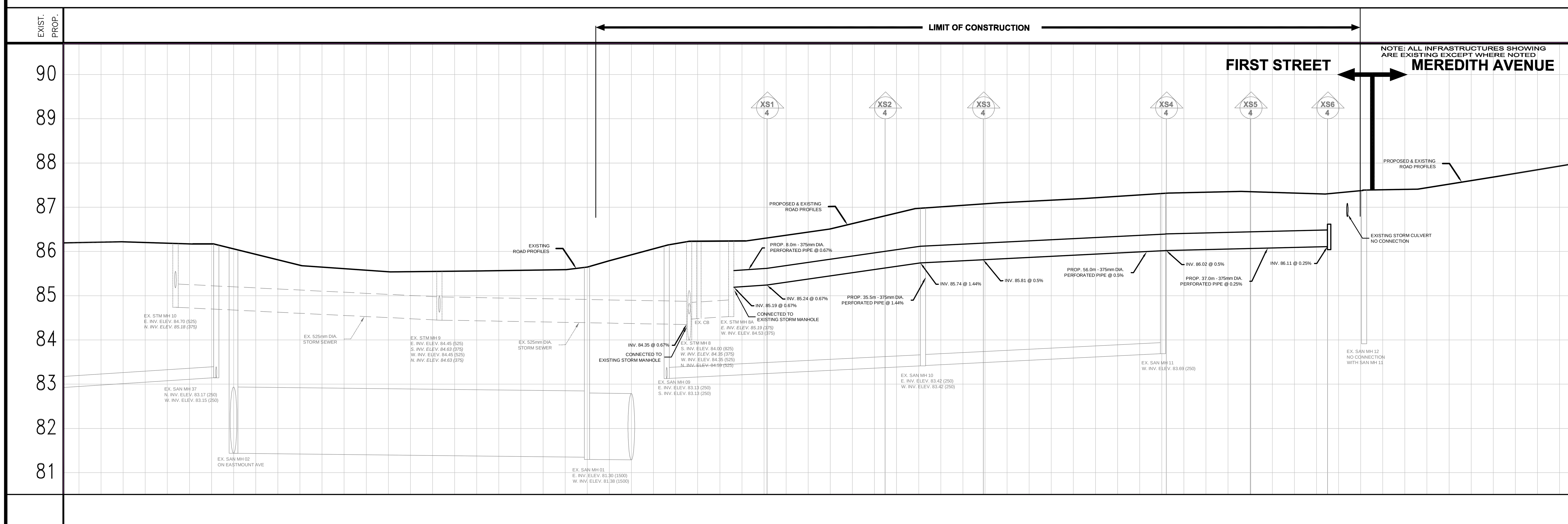


FIRST STREET



PROPOSED ℄ RD GRADES	86.21	86.17	85.82	85.58	85.59	85.58	85.93	86.24	86.44	86.87	87.08	87.19	87.31	87.35	87.33	87.44	87.77
STA	0−120	0−100	0−080	0−060	0−040	0−020	0+000	0+020	0+040	0+060	0+080	0+100	0+120	0+140	0+160	0+180	0+200

construction NORTH

true NORTH

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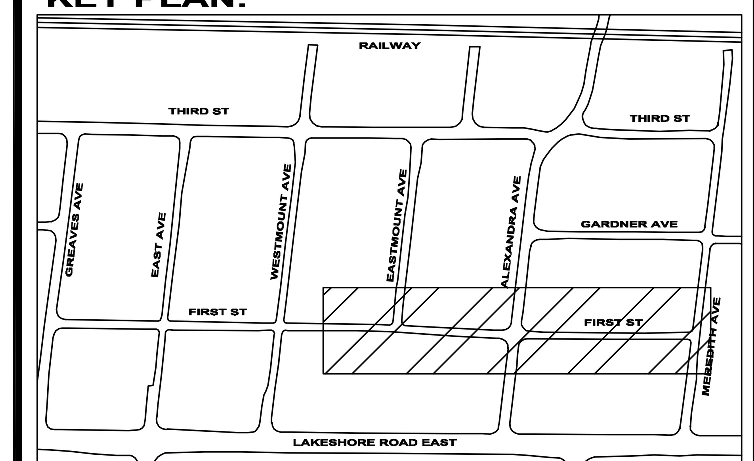

LEGEND

- CROSS - SECTION # / LOCATION SHEET #
- PROPERTY/ BUILDING LINE
- EXISTING TREE
- BIO-SWALE UNIT
- FLOW DIRECTION
- SEDIMENT LOGS
- CURB CUT
- EXISTING FENCE/HEDGE
- EXISTING TREE TO BE REMOVED
- PERFORATED PIPE
- SOLID PIPE
- OVERFLOW RISER
- BELL UTILITY LINE

GENERAL NOTES:

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REVISION	By	MM/DD/YY
RE - ISSUED FOR TENDER	PT	12/20/2011
ISSUED FOR TENDER	PT	06/09/2011

Aquafor Beech Limited
#6-202-2600 SKYMARK Ave,
MISSISSAUGA, ONTARIO, L4W 5B2
PHONE: (905) 629-0099, FAX: (905) 629-0089

MISSISSAUGA
Leading today for tomorrow

FIRST & THIRD STREET RECONSTRUCTION

PROJECT No.: 10128

PLAN AND PROFILE SHEET 1 OF 2

FIRST STREET

FROM STA. 0−120 TO STA. 0+200

DESIGNED BY:

APPROVED BY: LICENSED PROFESSIONAL ENGINEER P. K. TEWARI PROVINCE OF ONTARIO

DRAWN BY: CR/JH

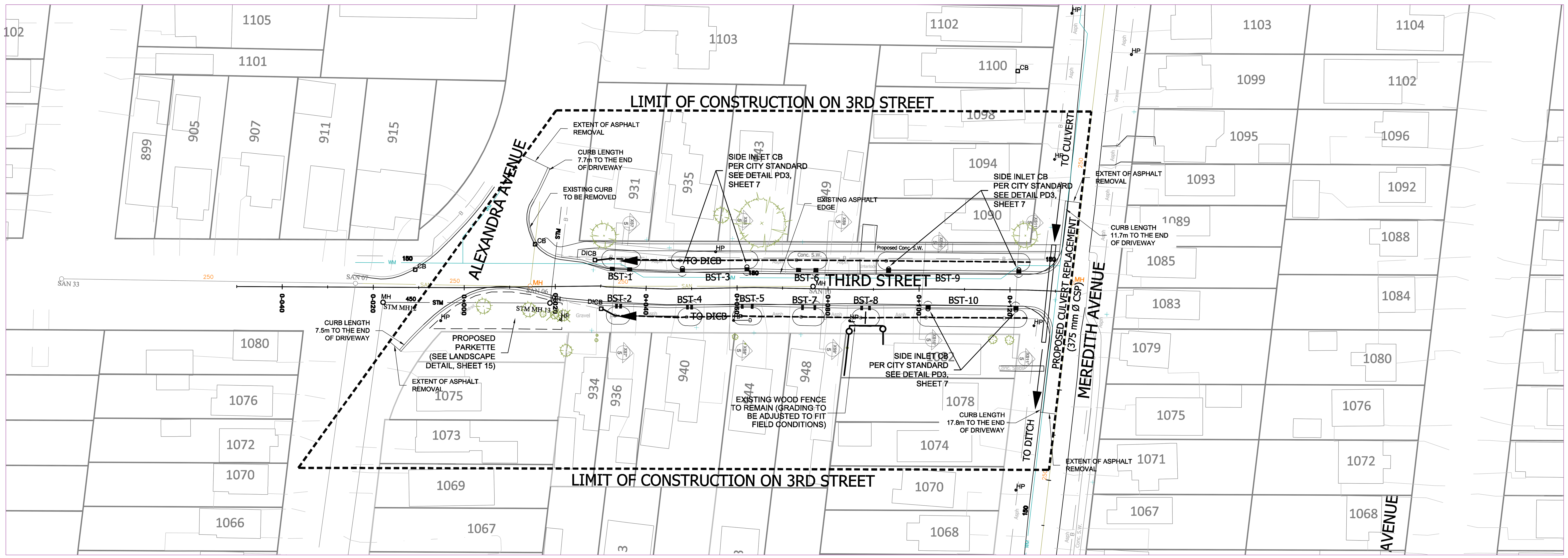
DATE: (MM.DD.YY) 12.20.11

SCALE: HOR.−1:500 VER.−1:50

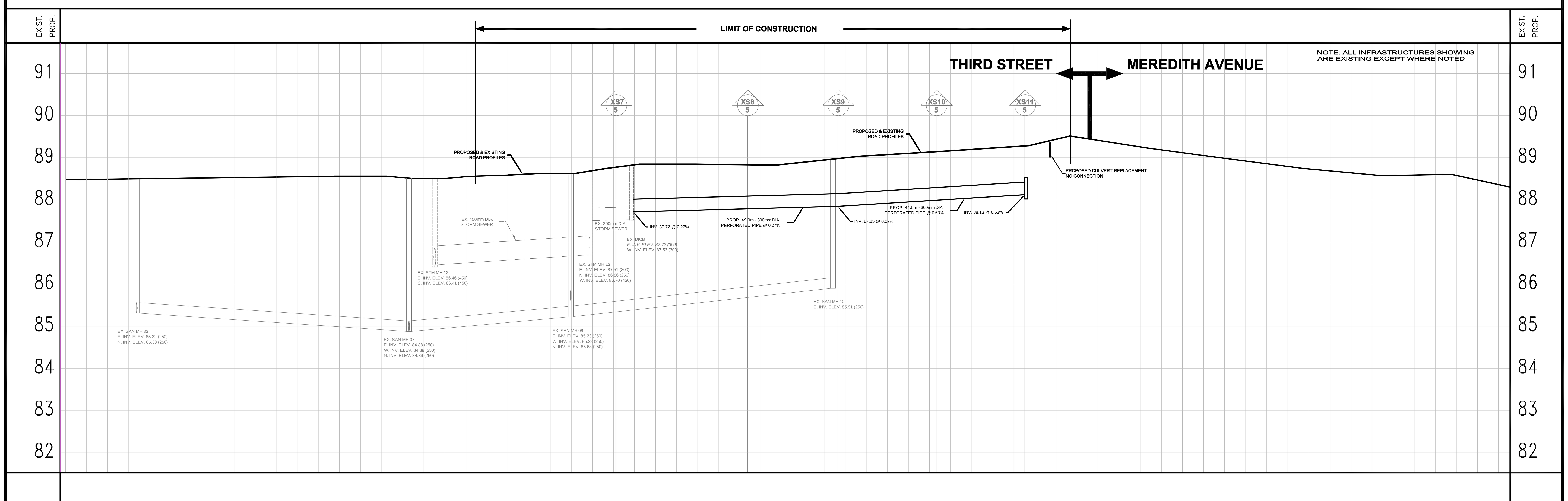
SHEET No. 1

DWG. No. PP-1

C48712



THIRD STREET



PROPOSED ℄ RD GRADES	88.49	88.51	88.54	88.56	88.51	88.59	88.70	88.85	88.83	89.00	89.14	89.27	89.42	89.12	88.86	88.65	88.60
STA	0-100	0-080	0-060	0-040	0-020	0+000	0+020	0+040	0+060	0+080	0+100	0+120	0+140	0+160	0+180	0+200	0+220

construction NORTH | true NORTH

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KEY PLAN:

LEGEND

- CROSS - SECTION #
- LOCATION SHEET #
- PROPERTY/ BUILDING LINE
- EXISTING TREE
- BIO-SWALE UNIT
- FLOW DIRECTION
- SEDIMENT LOGS
- CURB CUT
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RE - ISSUED FOR TENDER	PT	12/20/2011
ISSUED FOR TENDER	PT	06/09/2011

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#6-202-2600 SKYMARK Ave., MISSISSAUGA, ONTARIO, L4W 5B2
PHONE: (905) 629-0099, FAX: (905) 629-0089

MISSISSAUGA
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FIRST & THIRD STREET RECONSTRUCTION

PROJECT No.: 10128

PLAN AND PROFILE SHEET 2 OF 2

THIRD STREET

FROM STA. 0-100 TO STA. 0+220

DESIGNED BY: | APPROVED BY: P. K. TEJARA | DRAWN BY: CR/JH

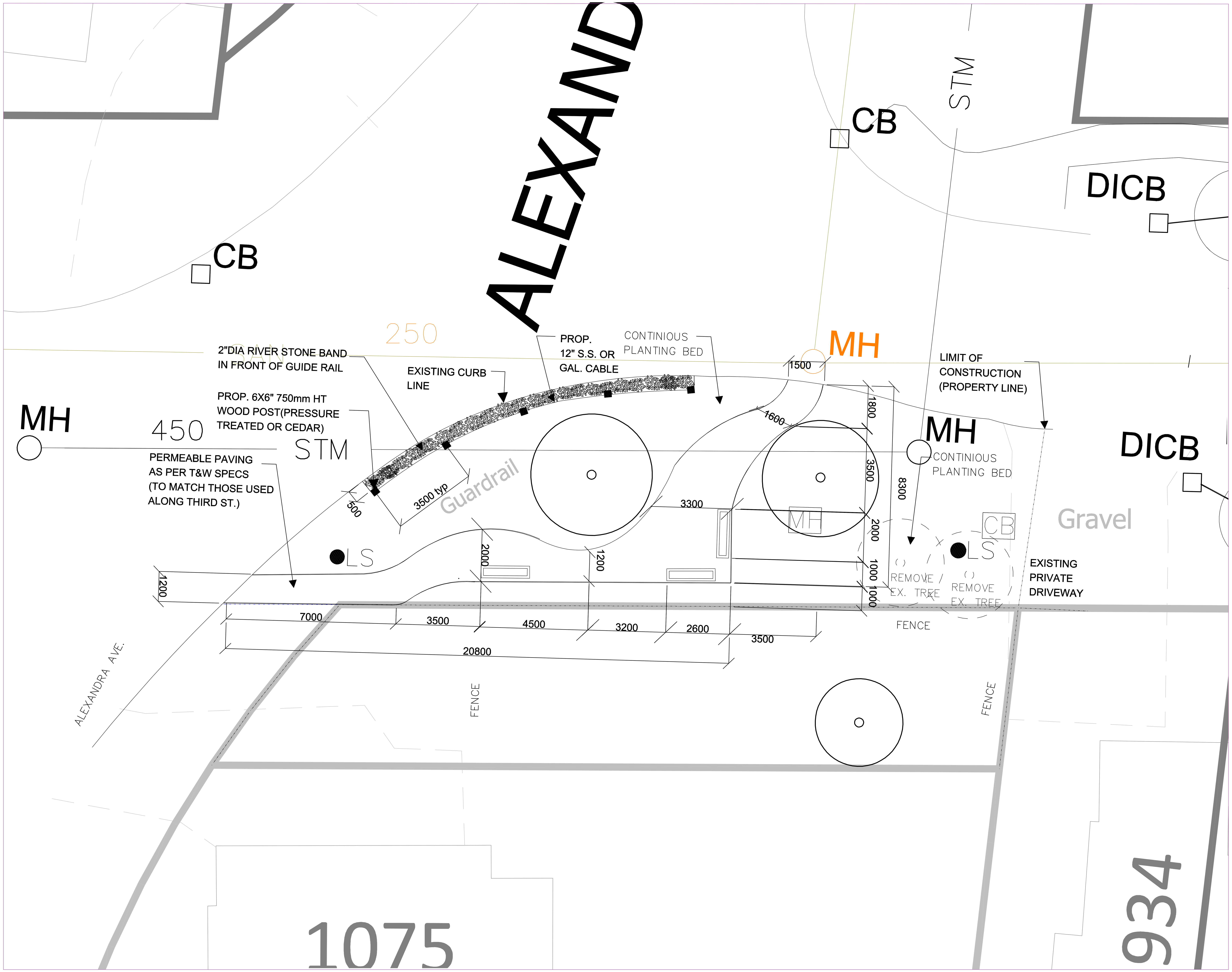
DATE: (MM.DD.YY) 12.20.11

SCALE: HOR.-1:500 VER.-1:50

SHEET No. 2

C48713

DWG. No. PP-2



construction NORTH | true NORTH

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KEY PLAN:

LEGEND

- PROPOSED GUARD RAIL
- CROSS - SECTION # LOCATION SHEET #
- EXISTING TREE TO REMAIN
- PROPERTY/ BUILDING LINE
- PROPOSED SHRUB OR GRASS
- EXISTING TREE
- EXISTING TREE FOR REMOVAL
- BIO-SWALE UNIT
- LS LIGHT STANDARD
- FLOW DIRECTION
- MH MANHOLE
- SEDIMENT LOGS
- CB CATCH BASIN
- CURB CUT
- BENCH

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LAYOUT PLAN NOTES:

1. SUPPLY AND INSTALL Three (3), 6' METAL BENCHES, PORT CREDIT MODEL #1077 BY TORONTO FABRICATING AND MANUFACTURING. CO, C/W SKATEBOARD DEFLECTORSBLACK, TAMPER PROOF S.S OR GALVANIZED BOLTS CONTACT ZABEDA, PHONE: 905 891 2516
2. ALL PLAN DIMENSIONS ARE IN MILLIMETERS UNLESS OTHERWISE NOTED.

REVISION	By	MM/DD/YY
RE - ISSUED FOR TENDER	PT	12/20/2011
ISSUED FOR TENDER	PT	06/09/2011

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MISSISSAUGA
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FIRST & THIRD STREET RECONSTRUCTION
PROJECT No.: 10128

PARKETTE DETAILS
THIRD STREET

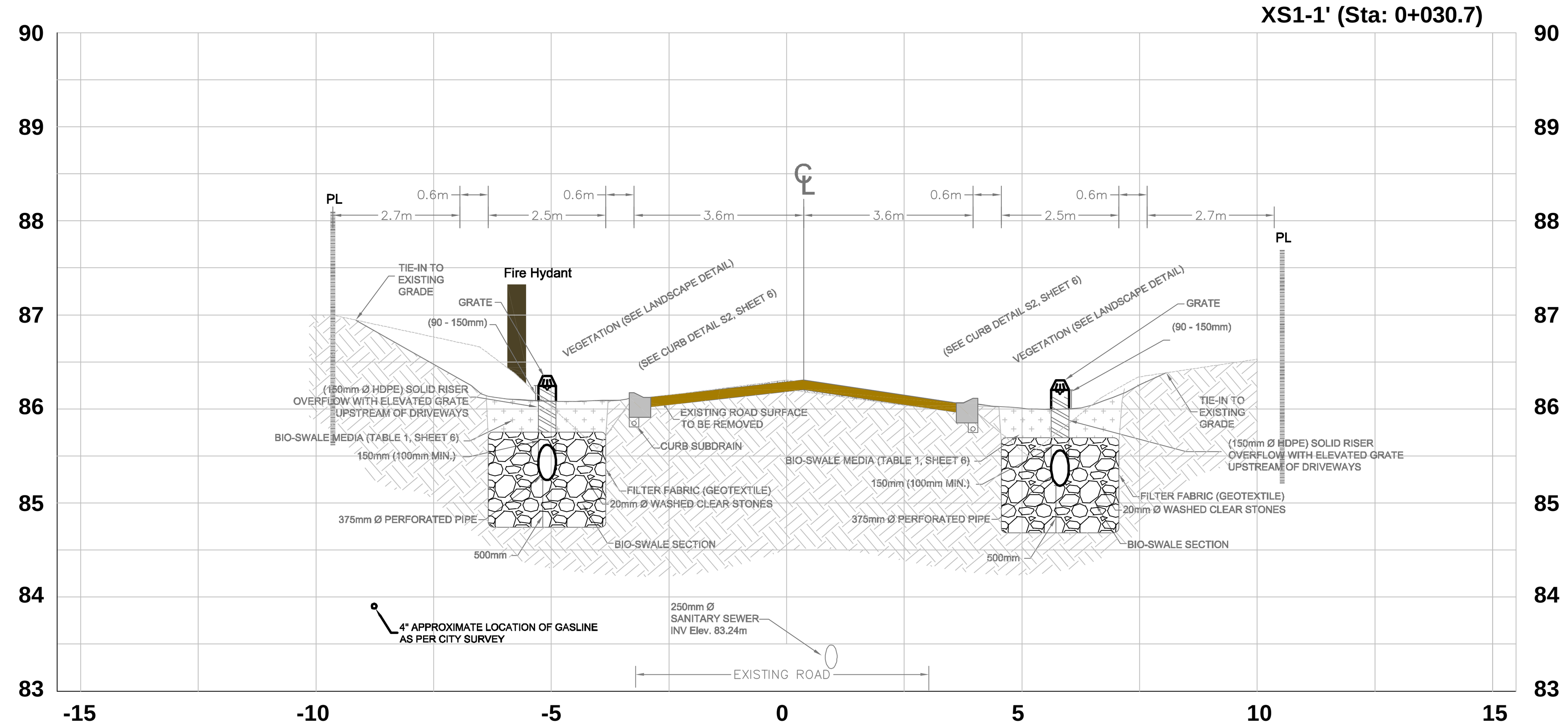
DESIGNED BY:

APPROVED BY:
LICENSED PROFESSIONAL ENGINEER P. K. TEWARI PROVINCE OF ONTARIO

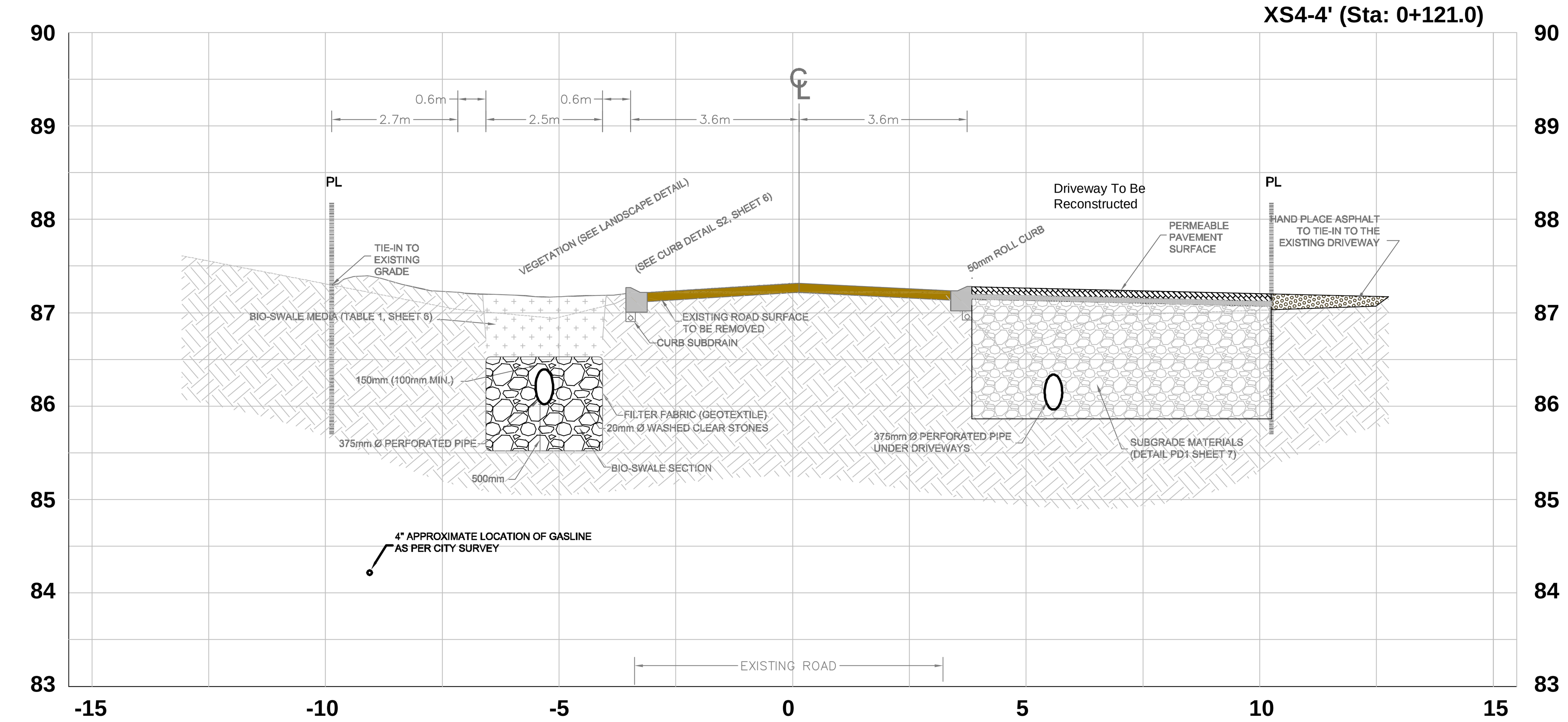
DRAWN BY: CR/JH
DATE: (MM.DD.YY) 12.20.11
SCALE: 1:75
SHEET No. 3
DWG. No. PP-3

C48715

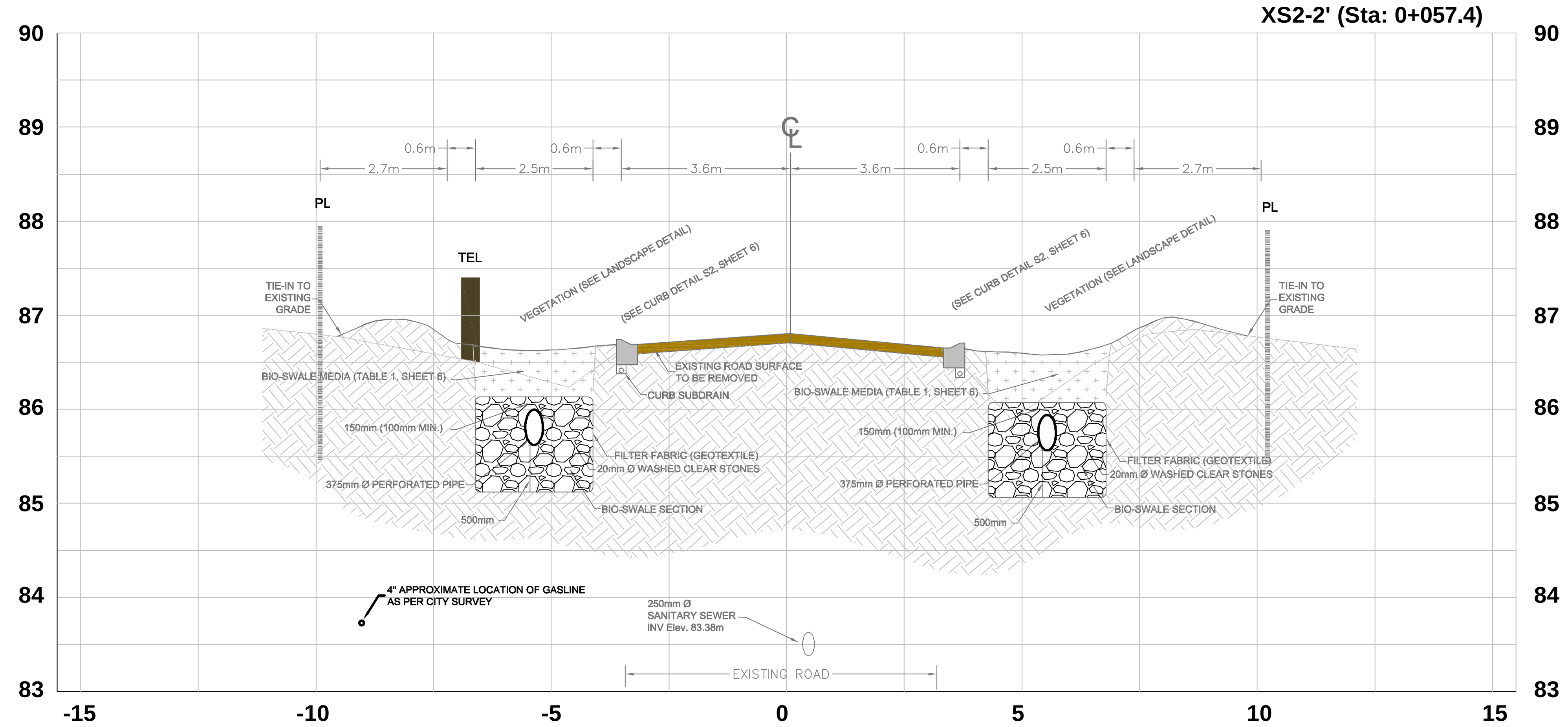
XS1-1' (Sta: 0+030.7)



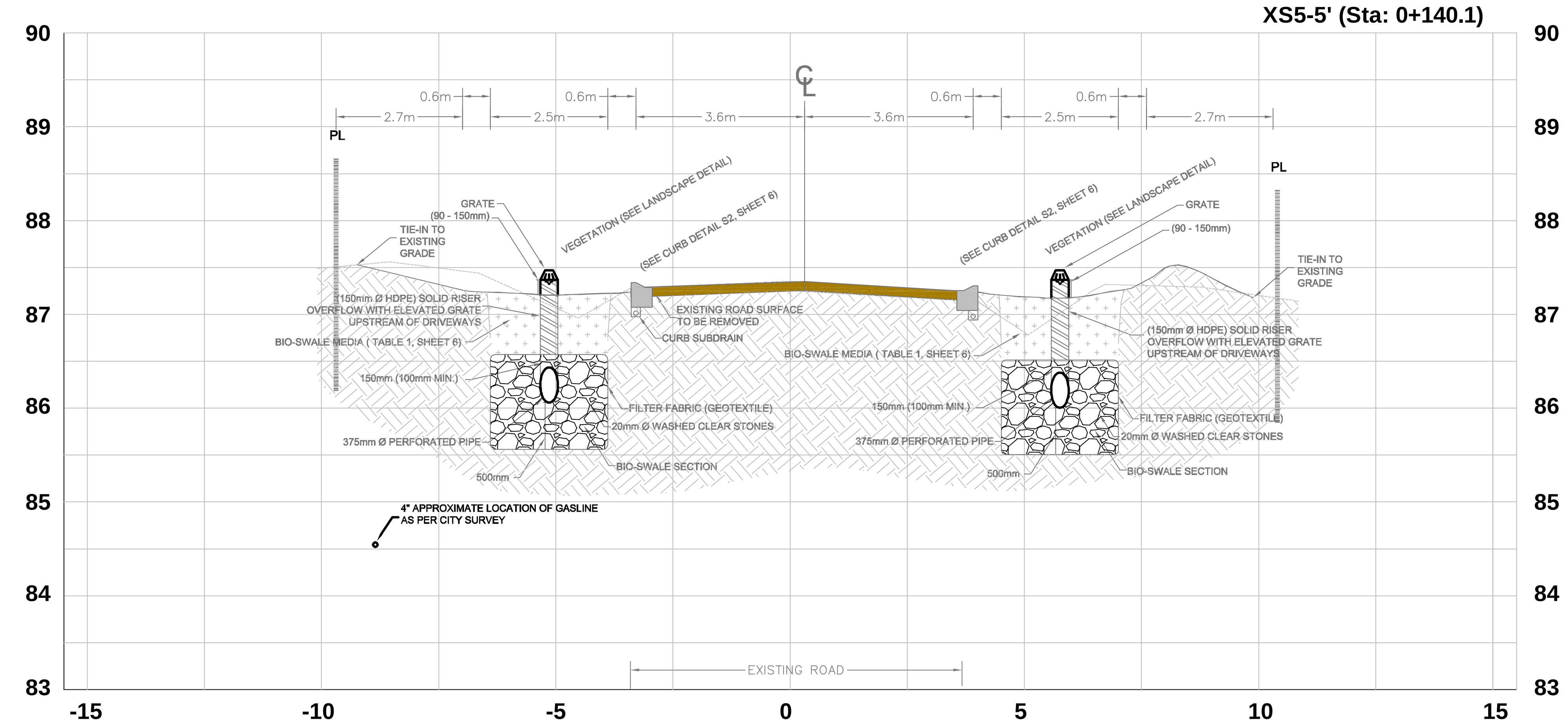
XS4-4' (Sta: 0+121.0)



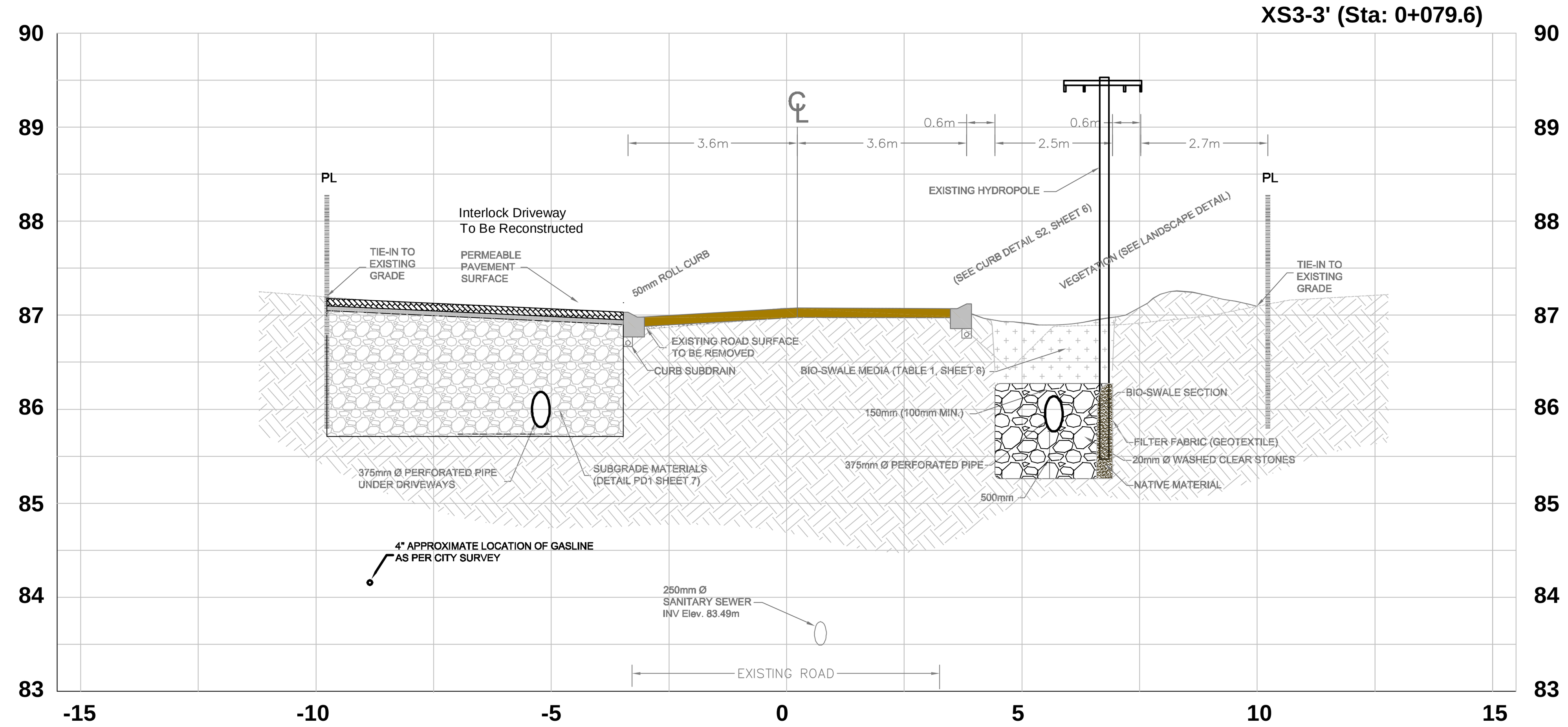
XS2-2' (Sta: 0+057.4)



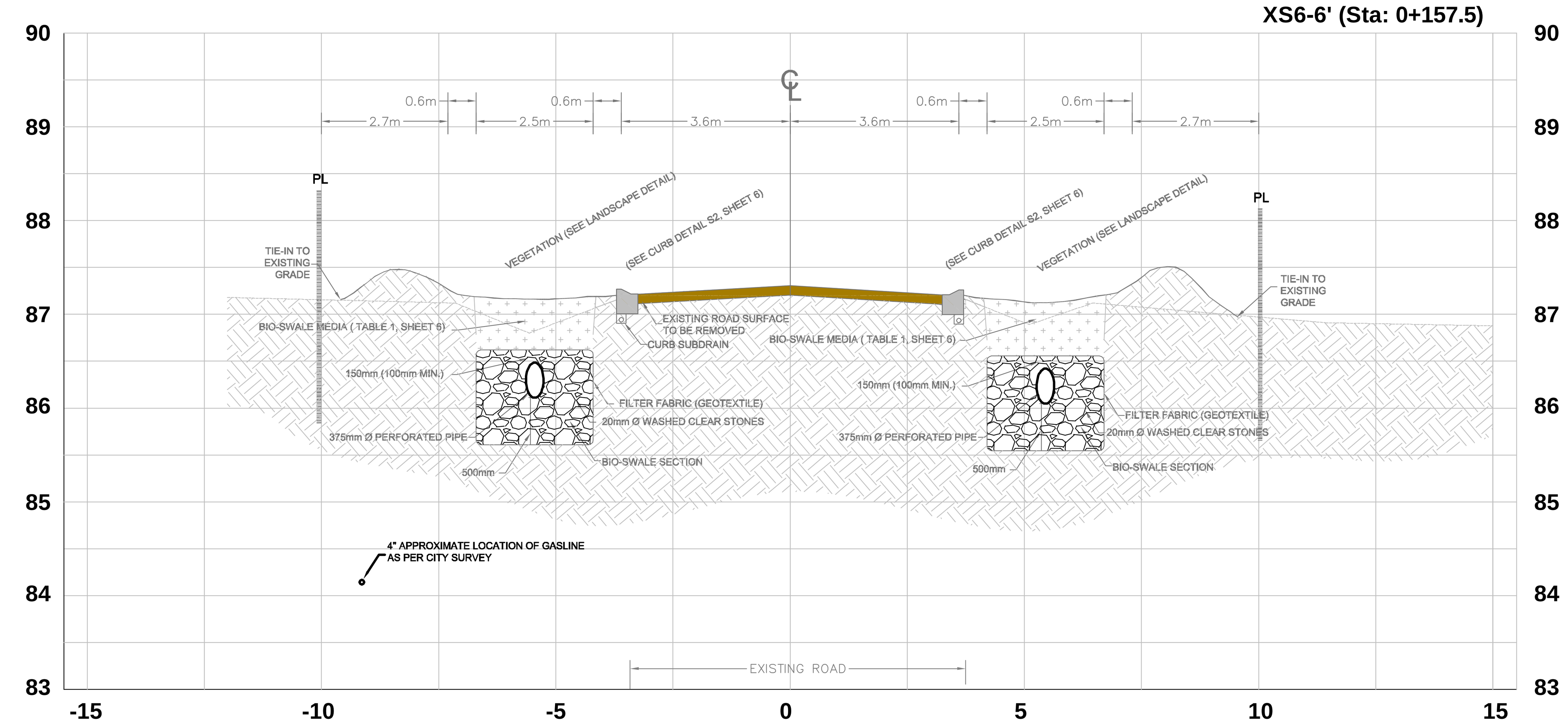
XS5-5' (Sta: 0+140.1)



XS3-3' (Sta: 0+079.6)



XS6-6' (Sta: 0+157.5)



construction NORTH | true NORTH

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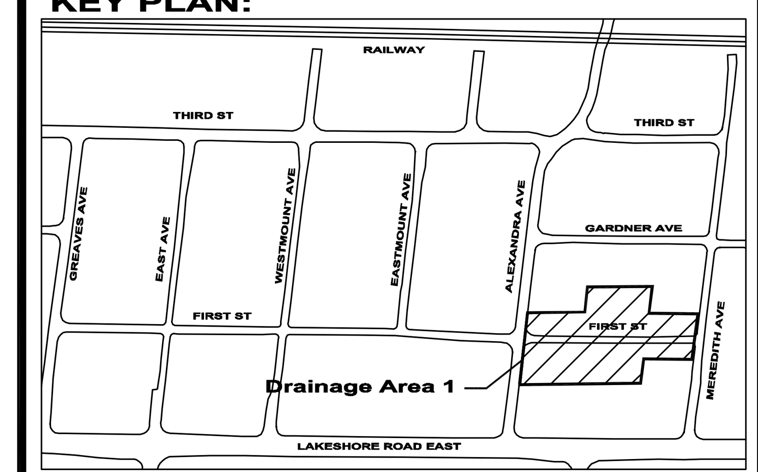

LEGEND

- CROSS - SECTION # / LOCATION SHEET #
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- SEDIMENT LOGS
- CURB CUT
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MISSISSAUGA, ONTARIO, L4W 5B2
PHONE: (905) 629-0099, FAX: (905) 629-0089

MISSISSAUGA
Leading today for tomorrow

FIRST & THIRD STREET RECONSTRUCTION

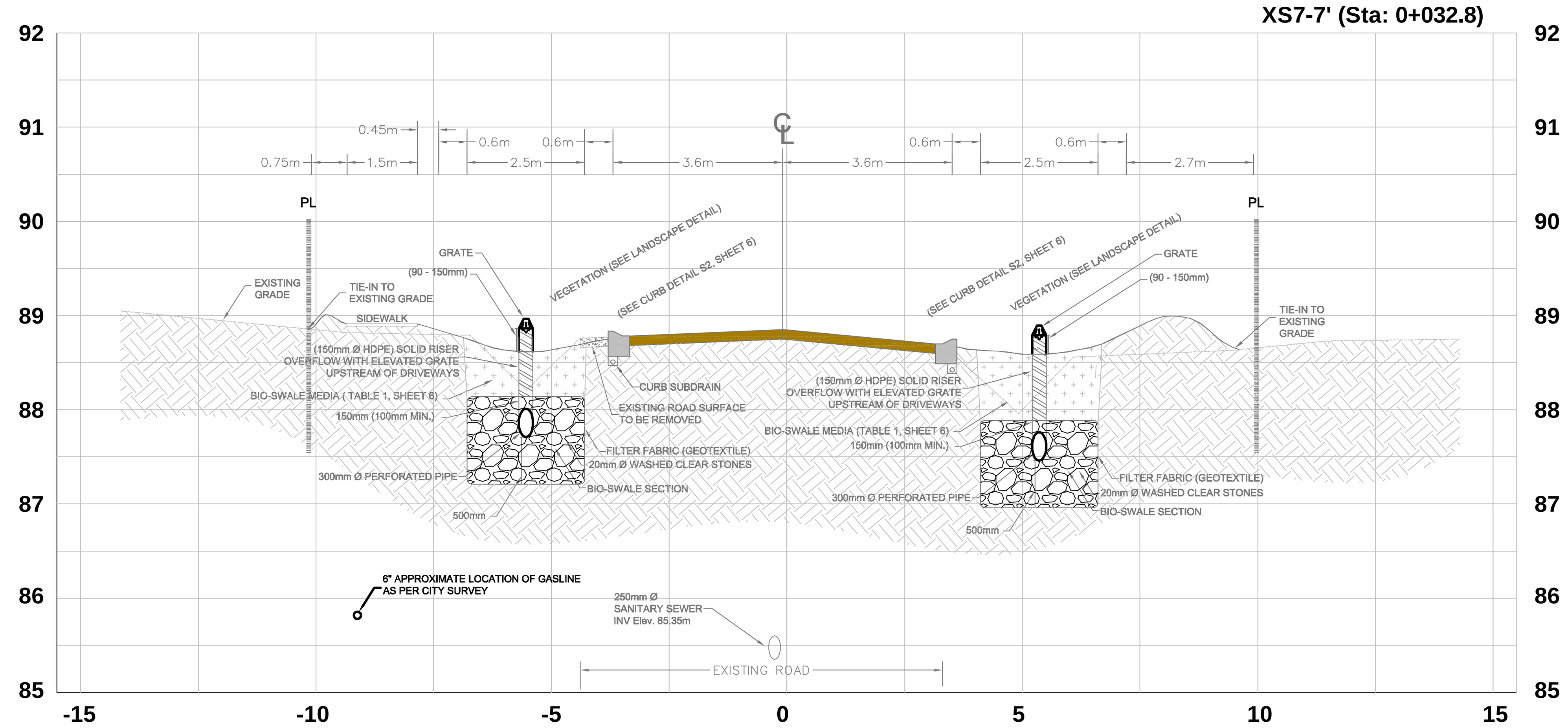
PROJECT No.: 10128

CROSS SECTIONS SHEET 1 OF 2

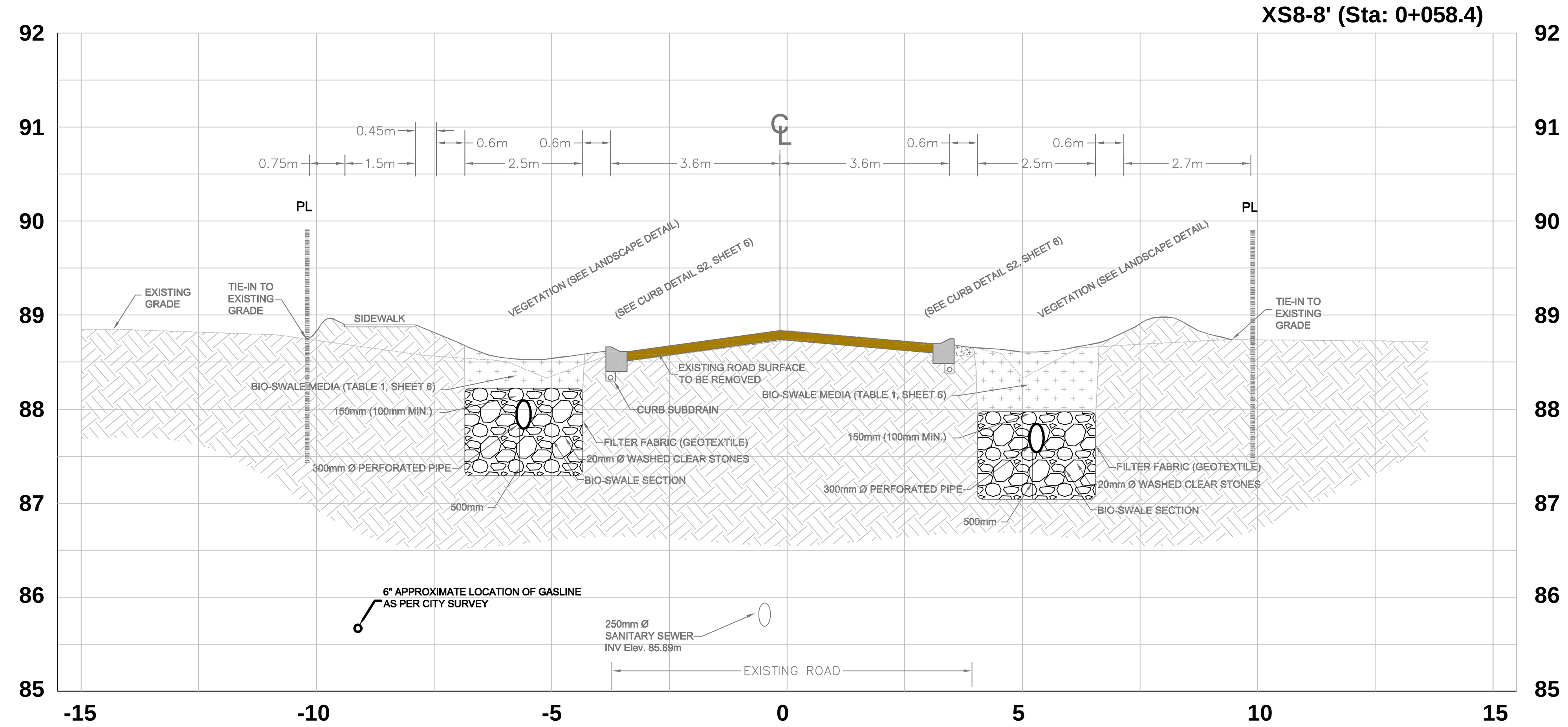
DRAINAGE AREA 1

DESIGNED BY:	APPROVED BY:	DRAWN BY: CR/JH
	P. K. TCHAMBI (LICENSED PROFESSIONAL ENGINEER, PROVINCE OF ONTARIO)	DATE: (MM.DD.YY) 12.20.11
		SCALE: HOR.-1:100 VER.- 1:50
		SHEET No. 4
C48715		DWG. No. CS-1

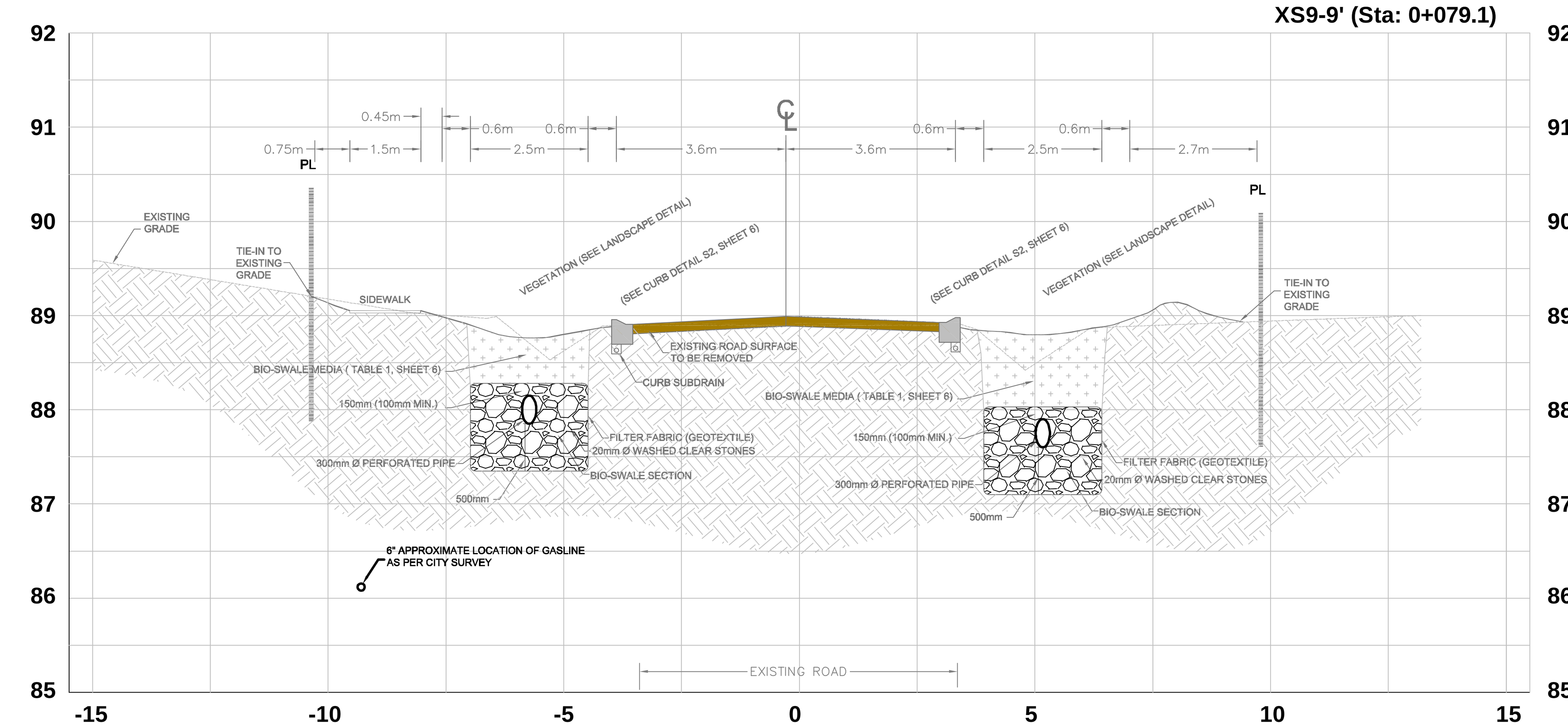
XS7-7' (Sta: 0+032.8)



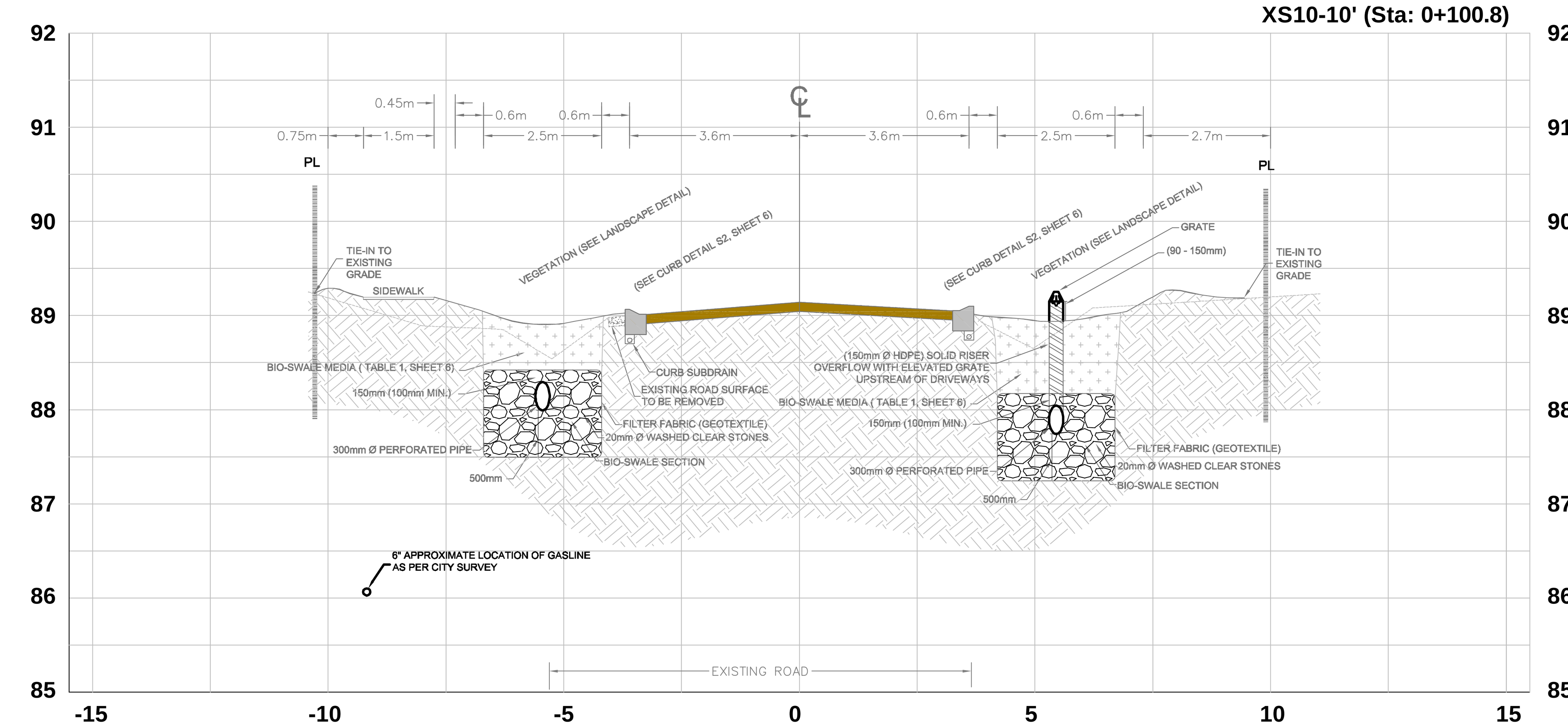
XS8-8' (Sta: 0+058.4)



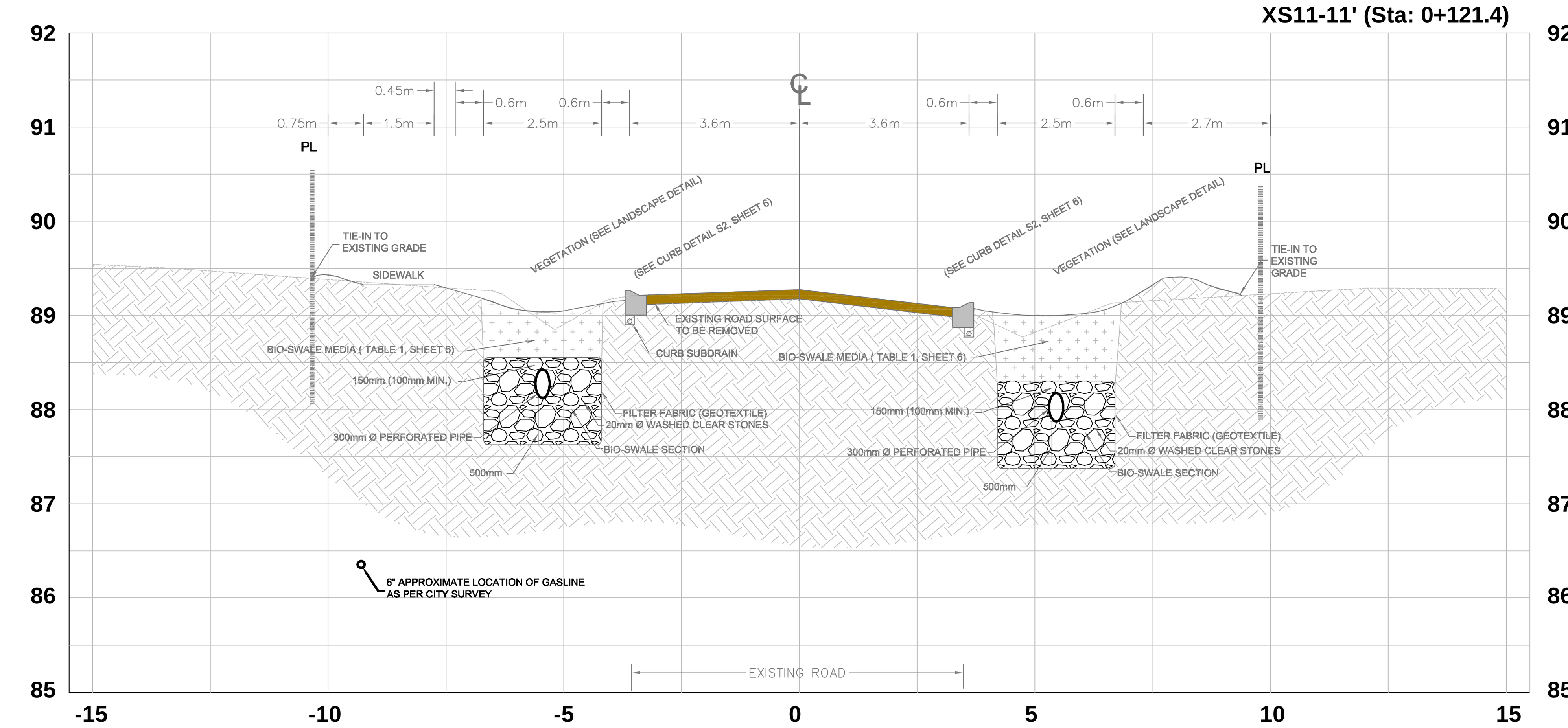
XS9-9' (Sta: 0+079.1)



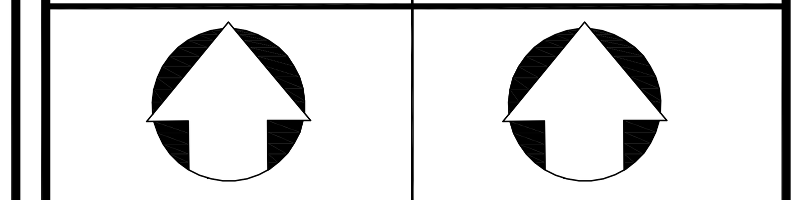
XS10-10' (Sta: 0+100.8)



XS11-11' (Sta: 0+121.4)



construction NORTH | true NORTH



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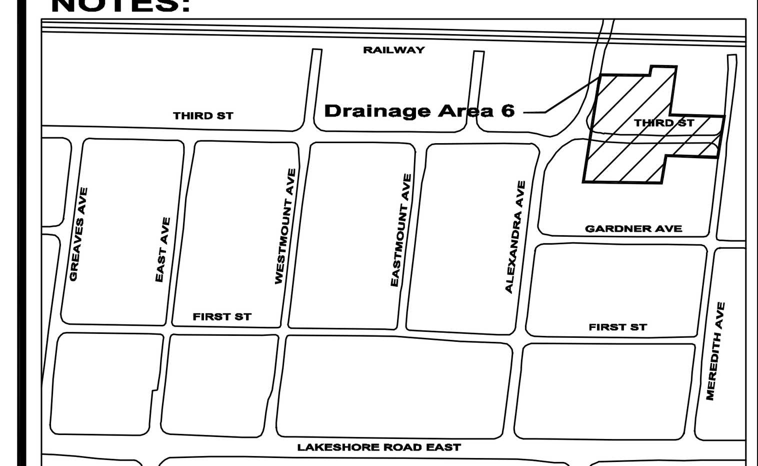

LEGEND

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- FLOW DIRECTION
- SEDIMENT LOGS
- CURB CUT
- EXISTING FENCE/HEDGE
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10. THE CONTRACTOR IS RESPONSIBLE FOR REMOVAL AND DISPOSAL OF ALL DEBRIS.
11. ALL SEDIMENTS AND EROSION CONTROL MEASURES SHALL BE INSPECTED DAILY TO ENSURE THAT THEY ARE FUNCTIONING PROPERLY AND ARE MAINTAINED AND/OR UPGRADED AS REQUIRED

REVISION	By	MM/DD/YY
RE - ISSUED FOR TENDER	PT	12/20/2011
ISSUED FOR TENDER	PT	06/09/2011

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MISSISSAUGA
Leading today for tomorrow

FIRST & THIRD STREET RECONSTRUCTION

PROJECT No.: 10128

CROSS SECTIONS SHEET 2 OF 2

DRAINAGE AREA 2

DESIGNED BY:	APPROVED BY:	DRAWN BY: CR/JH
	LICENSED PROFESSIONAL ENGINEER P. K. TEWARI PROVINCE OF ONTARIO	DATE: (MM.DD.YY) 12.20.11
		SCALE: HOR.-1:100 VER.- 1:50
		SHEET No. 5
C48716		DWG. No. CS-2

BIOSWALE GENERAL NOTES:

1. BIOSWALE MEDIA AS PER TABLE 1 SHOULD BE OBTAINED PREMIXED FROM JENKINS SOIL MIXTURES (905) 773-2000 OR EQUIVALENT. VENDOR TO PROVIDE TESTING RESULTS PRIOR TO INSTALLATION. DELIVERED MEDIA SHALL BE TESTED AND APPROVED BY FIELD ENGINEER PRIOR TO INSTALLATION. MEDIA INSTALLED WITHOUT FIELD ENGINEER CLEARANCE SHALL BE REMOVED AT THE CONTRACTOR'S EXPENSE IF DEEMED NECESSARY BY THE FIELD ENGINEER. THE CONTRACTOR WILL BE SOLELY RESPONSIBLE FOR ALL REQUIRED MEDIA TESTING EXPENSES. MEDIA TESTING RESULTS CAN BE EXPECTED APPROXIMATELY 2 - 3 WEEKS AFTER SUBMISSION TO LAB. THE CONTRACTOR IS RESPONSIBLE FOR ANY DELAYS SUFFERED AS A RESULT OF TESTING. NO COMPENSATION WILL BE PROVIDED FOR DELAYS DUE TO MEDIA ANALYSIS.

TABLE 1: MEDIA FOR BIOSWALE FACILITY

MEDIA	SIZE	% BY WEIGHT
1 - SAND	2 to 0.05mm	85 - 88%
2 - FINES	< 0.050mm	8 - 12%
3 - LEAF COMPOST (Organic Matter)	-	3 - 5%

Notes:
- CEC greater than 10 mg/100g
- PH = 5.5 - 7.5
- K greater than 25mm/hr

Soil Texture Classification:
- No objects greater than 50mm
- Media obtained from vendor to be tested to confirm design specifications prior to installation. Field engineer to confirm conformance with specification prior to installation.

2. UNDERDRAIN PERFORATED PIPE CONSTRUCTED IN ACCORDANCE WITH OPS 405. 10mm DIAMETER PERFORATIONS IN PIPE.ENDS TO BE CAPPED. NOTE: PIPES SHOULD TERMINATE 0.3m SHORT OF THE SIDES OF THE EXCAVATED OPENING

3. GEOTEXTILES SHALL BE PLACED ON THE (BOTTOM AND SIDES) OF SOIL SUBBASE. SECURE IN PLACE TO PREVENT WRINKLING AND OVERLAP A MINIMUM OF 0.3M IN THE DIRECTION TO DRAINAGE. GEOTEXTILE FABRIC MUST CONFORM TO OPSS 1860 FOR CLASS II GEOTEXTILE FABRICS. ACCEPTABLE FABRICS INCLUDE ONE OF THE FOLLOWING:

A) NON-WOVEN NEEDLE PUNCHED FABRICS MUST HAVE AN APPARENT OPENING SIZE (AOS) OF ≤0.3mm (MAXIMUM AVERAGE ROLL VALUE)

OR

B) WOVEN MONOFILAMENT FABRICS MUST HAVE A PERCENT OPEN AREA (POA) OF ≥ 4% UNACCEPTABLE FABRICS INCLUDE 'WOVEN SILT FILMS' AND OR 'NON-WOVEN HEAT BONDED FABRICS.

4. A VERTICAL OVERFLOW WITH 'CONE' OR 'BEEHIVE' GRATE IS TO BE INSTALLED FROM THE UNDERDRAIN TO THE BIOSWALE SURFACE TO ACCOMMODATE OVERFLOW CONDITIONS AS PER BIO-SWALE DETAIL AND CAN BE USED FOR MONITORING AND MAINTENANCE OF THE UNDERDRAIN SYSTEM.

5. SEDIMENT CONTROL FENCING TO BE INSTALLED PRIOR TO THE COMMENCEMENT OF CONSTRUCTION TO PREVENT RUNOFF FROM CONTAMINATING EXCAVATED SURFACE OF THE NATIVE SOILS AND OR THE AGGREGATE BASE COURSES AND OF THE BIO-SWALE.

6. FINAL GRADE OF THE BIOSWALE FACILITY TO BE EXCAVATED IMMEDIATELY PRIOR TO BACKFILLING WITH SPECIFIED AGGREGATE + MEDIA TO AVOID PREMATURE FACILITY CLOGGING.

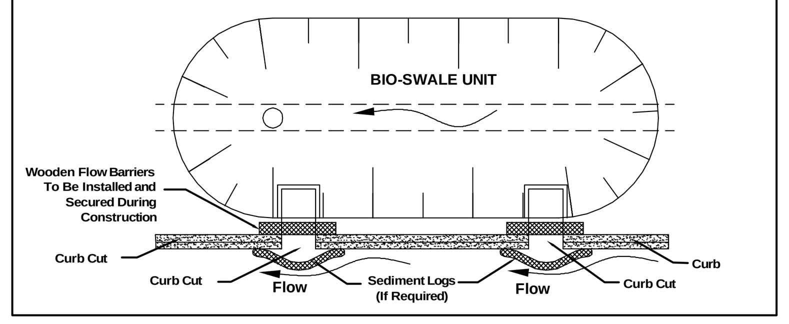
7. ALL CONSTRUCTION MATERIALS ARE TO BE STORED DOWN-GRADIENT OF EXCAVATED SITE WHENEVER POSSIBLE. MATERIALS STORED UP-GRADIENT OF THE EXCAVATED SITE ARE TO BE ENCLOSED BY APPROPRIATE SEDIMENT CONTROL FENCING.

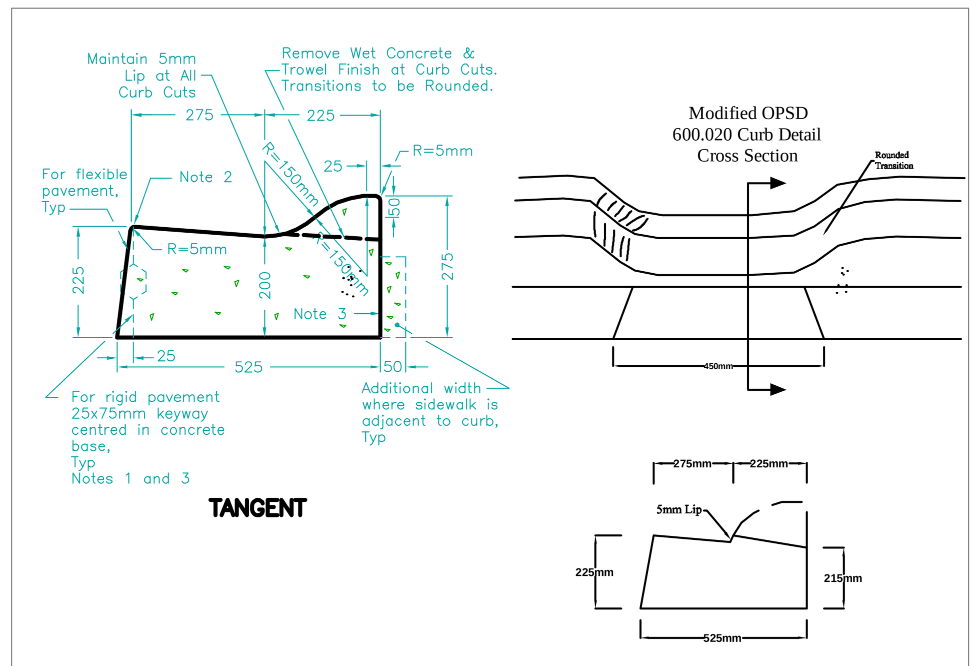
8. SEDIMENT LOGS/SOCKS TO BE PLACED & SCREENED AT ALL CURB CUT LOCATIONS & ENTRY POINTS TO PREVENT SEDIMENT ENTER INTO PROPOSED BIO-SWALE FACILITY.

CONSTRUCTION SEQUENCING:

1. SILT PROTECTION MEASURES ARE REQUIRED PRIOR TO THE COMMENCEMENT OF ANY AND ALL EXCAVATION ACTIVITIES.
2. ROUGH EXCAVATION OF THE BIOSWALE FACILITY IS PERMITTED TO A MAXIMUM 100mm OF FINAL GRADE. FINAL GRADE OF THE BIOSWALE FACILITY TO BE EXCAVATED IMMEDIATELY PRIOR TO BACKFILLING WITH SPECIFIED AGGREGATE + MEDIA TO AVOID PREMATURE FACILITY CLOGGING.
3. EXCAVATION, BACKFILLING AND MEDIA INSTALLATION IS ONLY TO OCCUR AFTER THE CONTRIBUTING DRAINAGE AREA HAS BEEN STABILIZED.
4. EXCAVATION OF FINAL 100mm OF NATIVE MATERIAL TO FINAL FACILITY INVERT AS PER DESIGN DRAWINGS AND INSTALL GEOTEXTILE FABRIC.
   - A - PLACE DESIRED DEPTH OF 19mm ø DOUBLE WASHED CLEAR STONE BENEATH UNDERDRAIN SYSTEM. SHOULD BE CLEAN WASHED; NO FINES SHOULD BE PRESENT IN MATERIAL (LESS THAN 1% PASSING 0.075MM SIEVE). (SEE GENERAL UNDERDRAIN/PERFORATED PIPE NOTES).
   - B - INSTALL UNDERDRAIN /PERFORATED PIPE AS PER DRAWING (THIS SHEET), PLACE REMAINING 19mm ø DOUBLE WASHED CLEAR STONE TO DESIGN ELEVATION. (SEE GENERAL UNDERDRAIN/PERFORATED PIPE NOTES).
   - C - APPLY BIOSWALE MEDIA IN 300mm LIFTS UNTIL DESIRED ELEVATION IS ACHIEVED. THOROUGHLY WET EACH LIFT BEFORE ADDING NEXT LIFT. ALLOW WATER TO FULLY PERCOLATE THROUGH THE SOIL BEFORE ADDING EACH COURSE.
   - D - FINISH GRADING:
     - A. THE BIOSWALE MEDIA SHALL BE FINE GRADED AFTER PLACEMENT. FINISHED GRADING SHALL CONFORM TO THE GRADE ELEVATIONS AND CONTOURS AS SHOWN ON THE DESIGN DRAWINGS AND SHALL BE FREE OF DEBRIS AND OTHER MATERIALS THAT WOULD BE DETRIMENTAL TO THE PERFORMANCE OF THE GROWING MEDIA.
     - B. THE FINISHED SURFACE SHALL BE SMOOTH AND UNIFORM, AND BE FIRM AGAINST DEEP FOOTPRINTING, WITH A FINE LOOSE SURFACE TEXTURE.
     - C. PROTECTION OF THE FINISHED GRADE AND CORRECTION OF ANY IRREGULARITIES CAUSED BY WORK OPERATIONS OVER THE FINISHED GRADE SHALL BE ENFORCED.
     - D. SETTLING OF ANY FINISHED GRADE SHALL NOT BE MORE THAN 10mm FROM SPECIFIED ELEVATIONS, AND IF SETTLING IS GREATER, THE CONTRACTOR SHALL BRING THE GRADE TO THE SPECIFIED ELEVATIONS.
5. PLANTING NOT TO OCCUR PRIOR TO 5 DAYS AFTER MEDIA PLACEMENT TO ALLOW FOR MEDIA SETTLEMENT. ADD ADDITIONAL MEDIA IF REQUIRED.
6. PLANTING IS TO OCCUR IN ACCORDANCE WITH THE BIOSWALE PLANTING PLAN. AS NECESSARY, PROVIDE A MINIMUM OF 1 IRRIGATION PER WEEK IN THE FIRST 2 MONTHS.
7. AFTER PLANTING, 75mm OF SHREDDED HARDWOOD MULCH (AGED A MINIMUM OF 12 MONTHS) IS TO BE PLACED ON TOP OF THE BIOSWALE MEDIA AND AROUND PLANT MATERIAL.
8. BIOSWALE FACILITY SHOULD BE INSPECTED BY THE CONTRACTOR AFTER EACH STORM > 10mm OR A MIN. OF TWICE POST INSTALLATION DURING THE FIRST 6 MONTHS AFTER PLACING THE FACILITY ON-LINE. ANY DEVIATIONS FROM DESIGN DRAWINGS TO BE CORRECTED.
9. BIOSWALE FACILITY TO BE INSPECTED A MIN. ONCE ANNUALLY (TYPICALLY IN SPRING) AND AFTER EACH EVENT GREATER THAN 60mm.

SEDIMENT LOG DETAIL





NOTES:

1 When curb and gutter is adjacent to concrete pavement or base, this drawing is to be used in conjunction with OPSD–552.010 and 552.020.
2 Flexible and composite pavement shall be placed 5mm above the adjacent edge of gutter.
3 For slipforming procedure, a 5% batter is acceptable.
A Treatment at entrances shall conform with OPSD–351.010.
B Outlet treatment shall conform with OPSD–610 Series.
C The length of transition from one curb type to another shall be 3.0m, except in conjunction with quide rail, it shall conform to OPSD–900 Series.
D All dimensions are in millimetres unless otherwise shown.

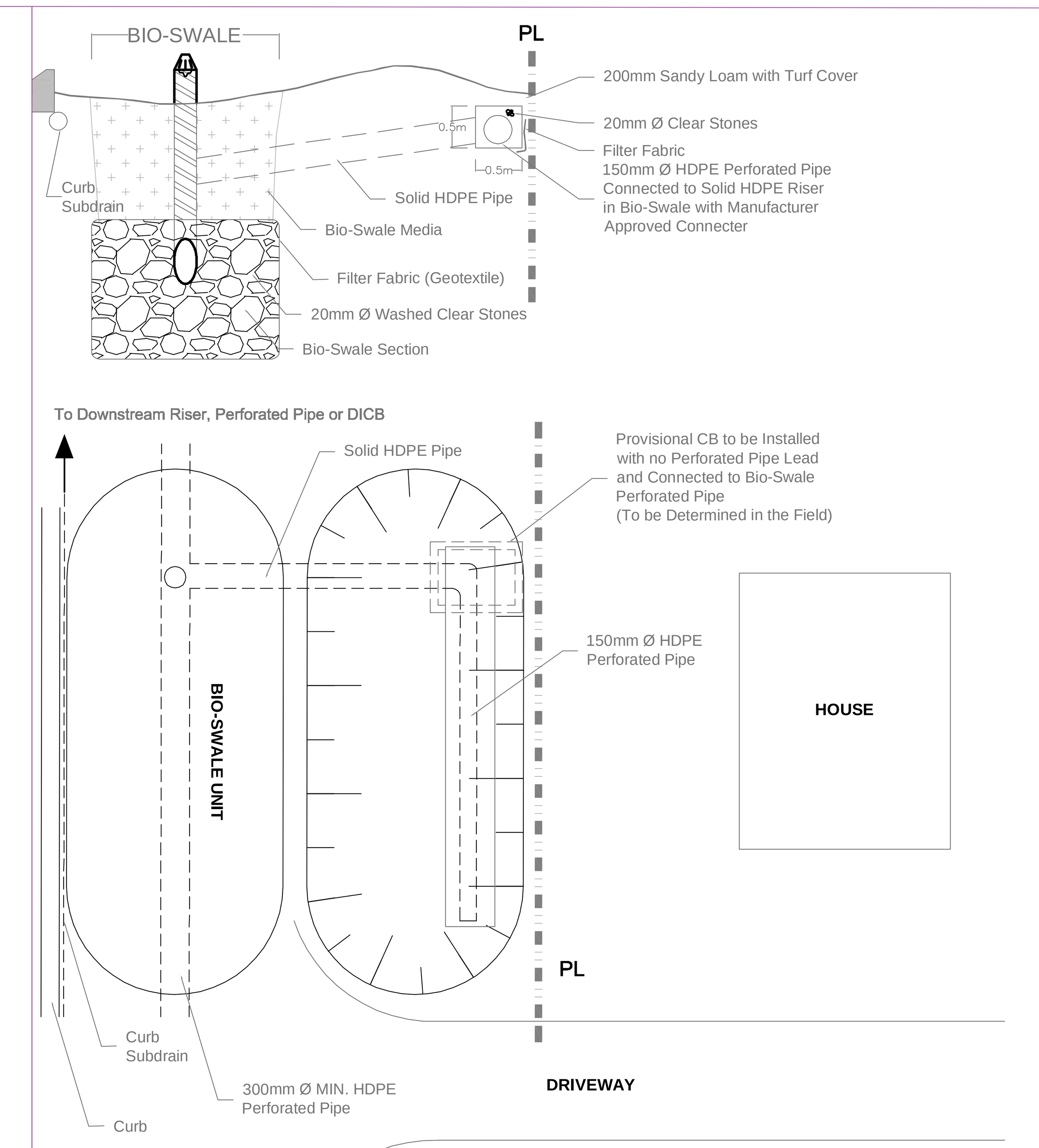
LEGEND:

S – Rate of pavement superelevation in percent, %.

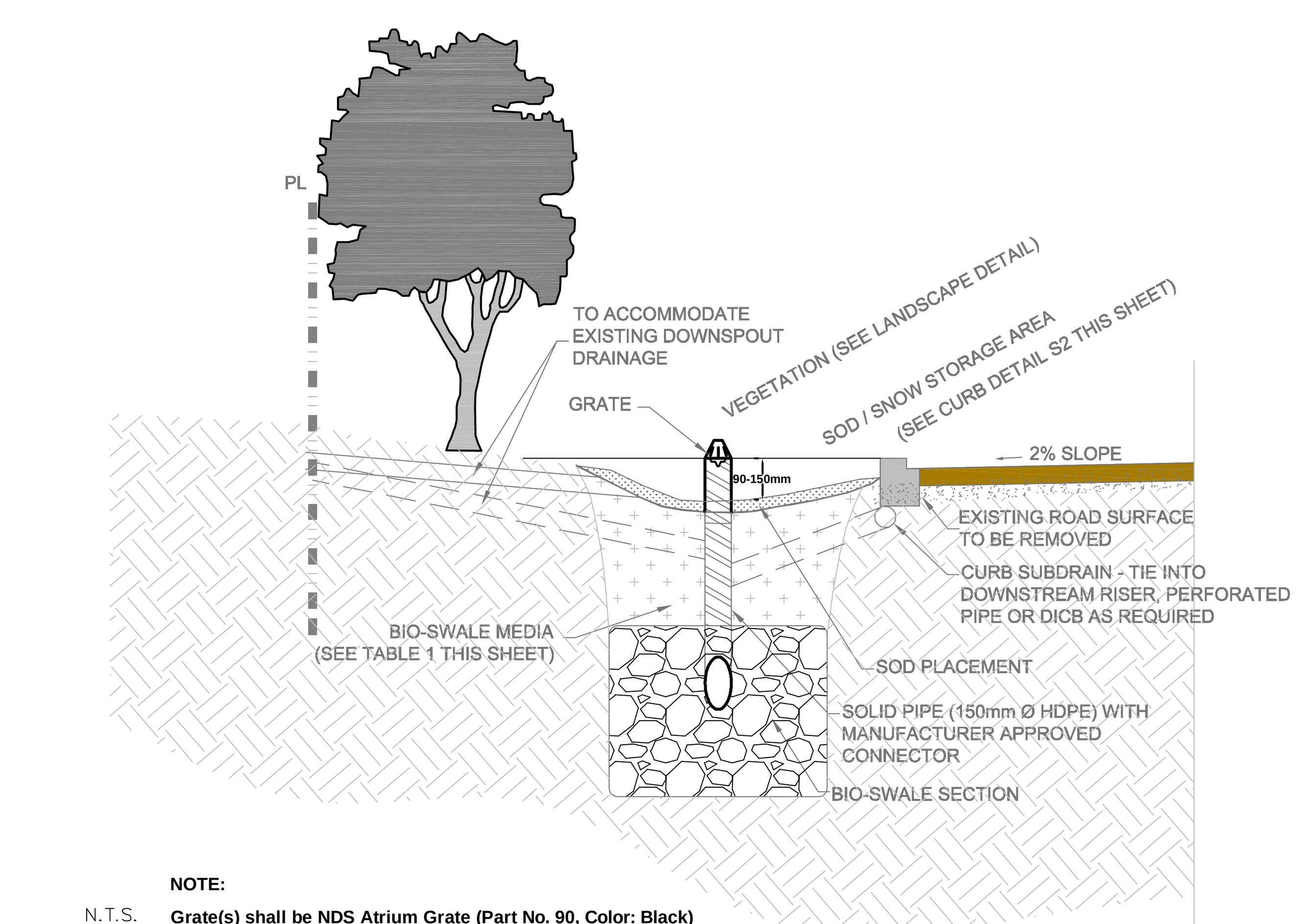
ONTARIO PROVINCIAL STANDARD DRAWING | April 1999 | Rev

CONCRETE SEMI–MOUNTABLE CURB WITH STANDARD GUTTER

DETAIL S2
STANDARD DETAIL FOR CURB AND GUTTER (REVISED O.P.S.D 600.060)
N.T.S.



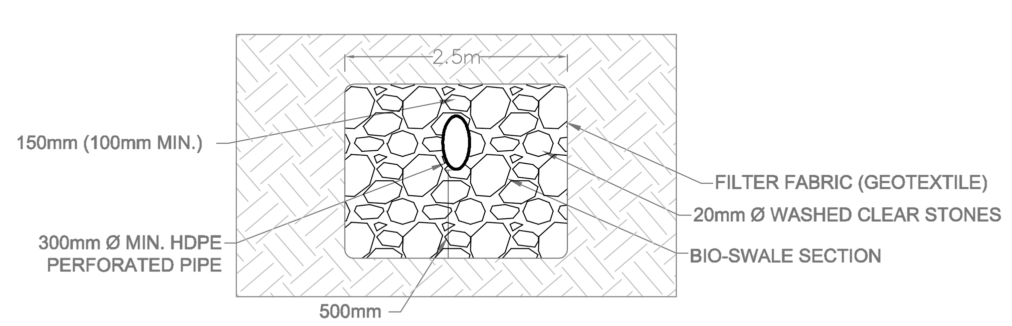
DETAIL S1
SUBSURFACE DRAIN DETAIL (N.T.S.)



N.T.S.

NOTE:
Grate(s) shall be NDS Atrium Grate (Part No. 90, Color: Black) by Waterline Products (905) 625 - 9440 or EMCO (905) 564 - 7788 or Equivalent.

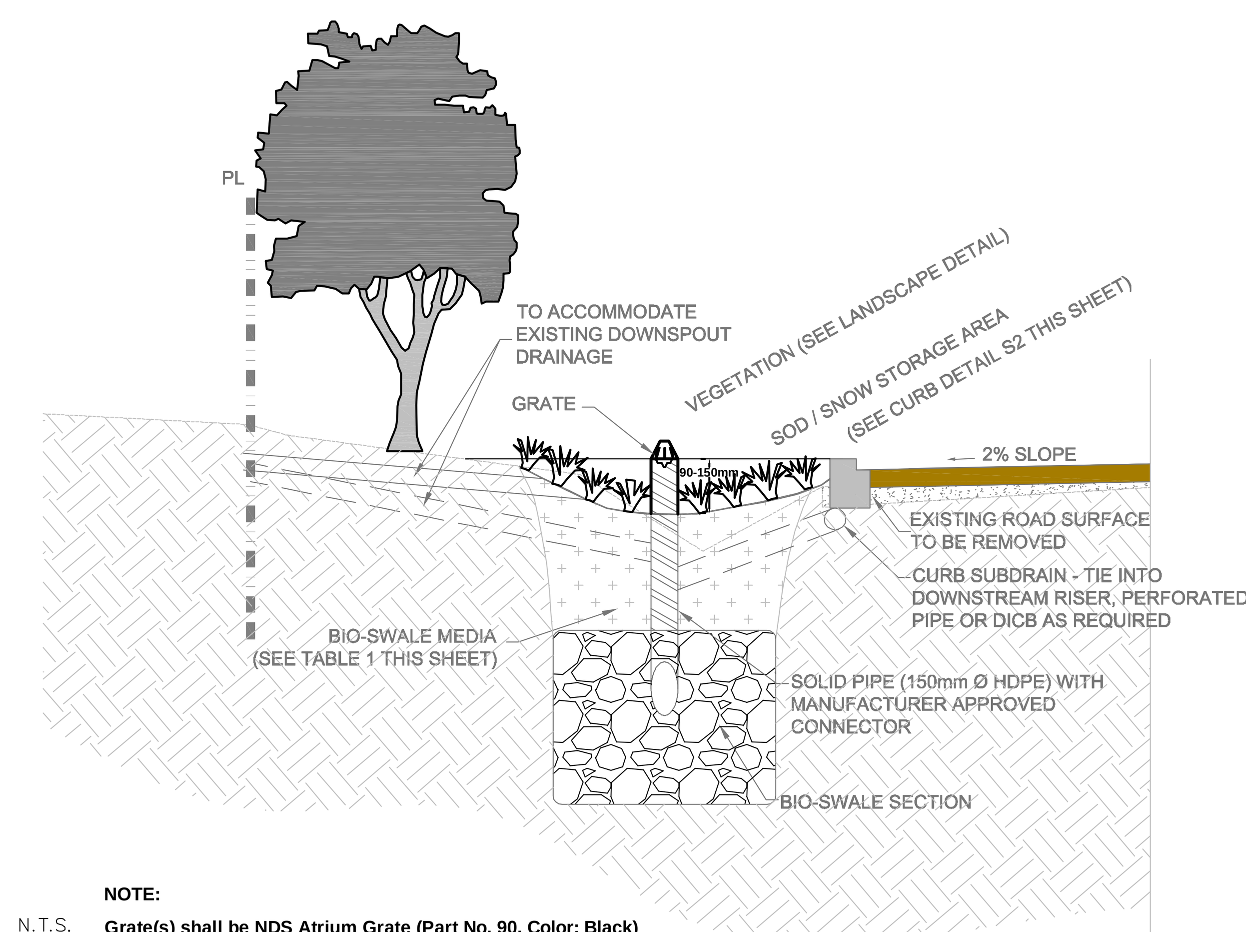
BIO-SWALE DETAIL



N.T.S.

UNDERDRAIN DETAIL

DETAIL S3A
BIO-SWALE TYPICAL CROSS-SECTION (SOD PLACEMENT)
N.T.S.



N.T.S.

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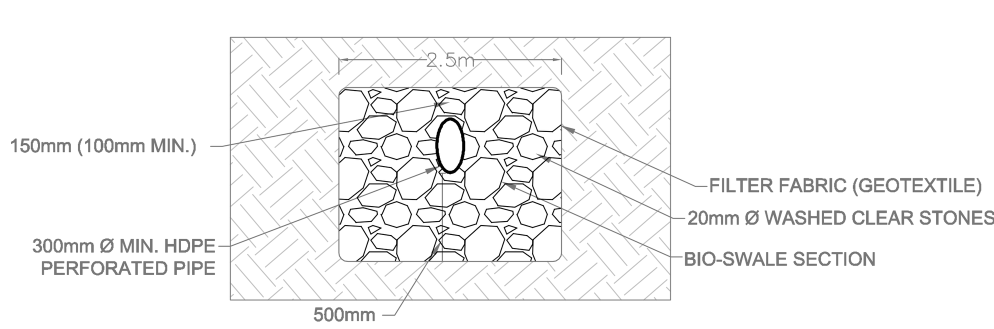
BIO-SWALE DETAIL

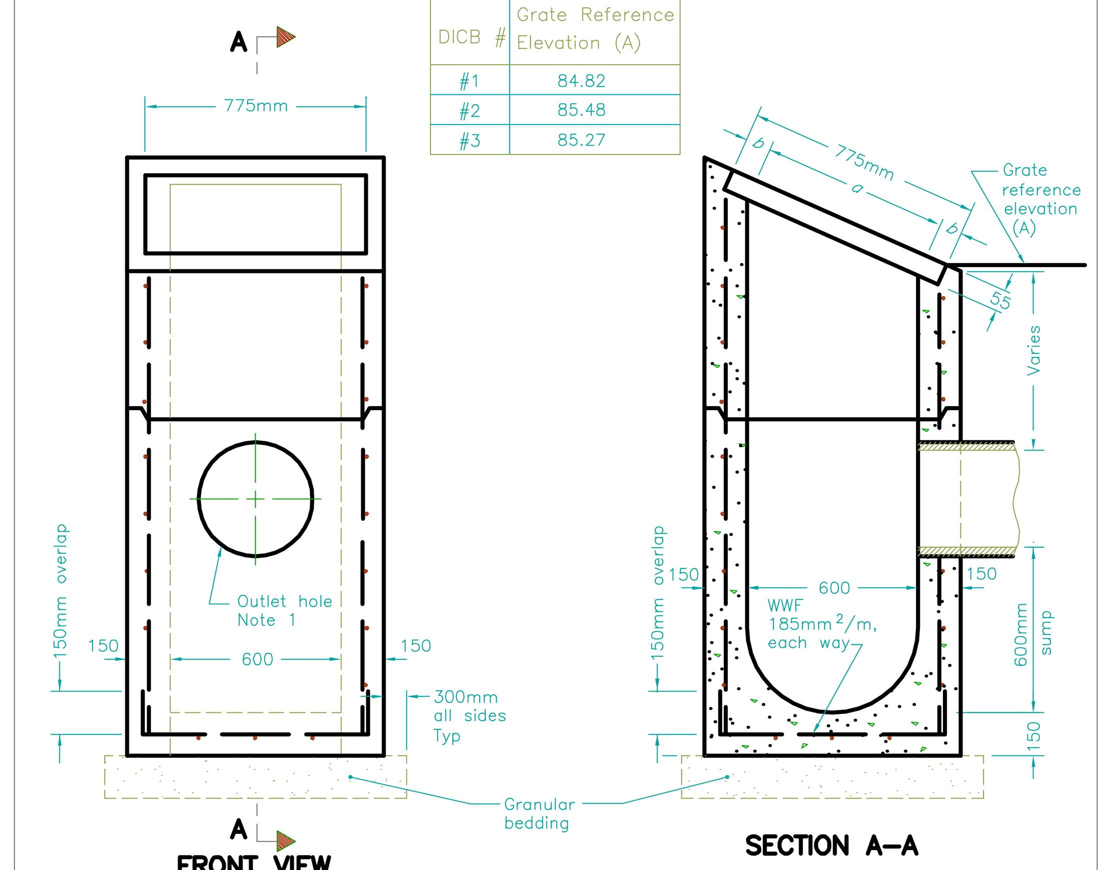


N.T.S.

UNDERDRAIN DETAIL

DETAIL S3B
BIO-SWALE TYPICAL CROSS-SECTION
N.T.S.

DICB #	Grate Reference Elevation (A)
#1	84.82
#2	85.48
#3	85.27



NOTES:

1 Outlet hole size 525mm maximum diameter, location as required.
A Where inlet is placed across ditch and is accessible to vehicular traffic, grating slope is to be 6:1 or flatter.
B All reinforcing steel shall have 25mm minimum cover.
C Granular backfill to be placed to a minimum thickness of 300mm all around the ditch inlet.
D Grating according to OPSD–403.010.
E Pipe support according to OPSD–708.020.
F All dimensions are nominal.
G All dimensions are in millimetres or metres unless otherwise shown.

Opening Dimensions mm			
Grate Type	Grate Slope	a	b
A	2:1	670	52
	3:1	632	72
	4:1	618	79
	6:1	608	83
	8:1	605	85
	10:1	603	86
	HOR	600	87

ONTARIO PROVINCIAL STANDARD DRAWING | 1996 09 15 | Rev

PRECAST CONCRETE DITCH INLET
600mm x 600mm, DEPTH 4.0m MAX

Date

OPSD – 705.030

DETAIL S4
STANDARD DETAIL FOR GRATE STRUCTURE (O.P.S.D 705.030)
N.T.S.

construction NORTH | true NORTH

THE POSITION OF THE POLE LINES, CONDUITS, WATERMAINS, SEWERS, AND OTHER UTILITIES AND STRUCTURES ARE N O T NECESSARILY SHOWN ON THE CONTRACT DRAWINGS, AND WHERE SHOWN, THE ACCURACY OF THE POSITION OF SUCH UTILITIES AND STRUCTURES IS NOT GUARANTEED.

BEFORE STARTING WORK

THE CONTRACTOR SHALL CONFIRM THE POSITION AND EXACT LOCATION OF ALL SUCH UTILITIES, AND SHALL ASSUME ALL LIABILITY FOR ANY DAMAGE TO THEM MADE DURING THE COURSE OF THE CONTRACT WORK.

NOTES:

LEGEND

- CROSS - SECTION # / LOCATION SHEET #
- PROPERTY/ BUILDING LINE
- EXISTING TREE
- BIO-SWALE UNIT
- FLOW DIRECTION
- SEDIMENT LOGS
- CURB CUT
- EXISTING FENCE/HEDGE
- EXISTING TREE TO BE REMOVED
- PERFORATED PIPE
- SOLID PIPE
- OVERFLOW RISER

GENERAL NOTES:

1. THIS SET OF DRAWINGS TO BE READ IN CONJUNCTION WITH ACCOMPANYING DESIGN BRIEF.
2. ALL ELEVATIONS ARE IN METRES AND REFERENCED TO LOCAL DATUM. ALL DIMENSIONS ARE IN METRIC UNITS.
3. THE CONTRACTOR SHALL BE RESPONSIBLE FOR LAYOUT AND SURVEY CONTROL DURING CONSTRUCTION.
4. THE CONTRACTOR IS RESPONSIBLE FOR LOCATION OF ALL EXISTING UTILITIES PRIOR TO CONSTRUCTION.
5. THE CONTRACTOR SHALL DELINEATE THE REQUIRED WORKING AREA ON-SITE PRIOR TO THE START OF WORK AND SHALL CONFINE OPERATIONS WITHIN THE DEFINED AREA. ALL ACTIVITIES, INCLUDING MAINTENANCE PROCEDURES, WILL BE CONTROLLED TO PREVENT ENTRY OF PETROLEUM PRODUCTS, DEBRIS, RUBBLE, CONCRETE OR OTHER DELETERIOUS SUBSTANCES INTO ANY WATER/WATERCOURSE/WETLAND NATURAL FEATURE, STORM SEWER OR SANITARY SEWER.
6. EROSION AND SEDIMENT CONTROL MEASURES (AND TREE/SHRUB PROTECTION BARRIERS) WILL BE IMPLEMENTED PRIOR TO AND MAINTAINED DURING THE CONSTRUCTION PHASES TO PREVENT ENTRY OF SEDIMENT INTO ANY FUTURE BIOSWALE OR PERMEABLE PAVEMENT FACILITY. THESE EROSION AND SEDIMENT CONTROL MEASURES WILL BE REMOVED FOLLOWING CONSTRUCTION COMPLETION AND WHEN DISTURBED AREAS HAVE BEEN STABILIZED AND VEGETATION ESTABLISHED.
7. ALL AREAS WHICH REMAIN DISTURBED FOR MORE THAN 30 DAYS MUST BE STABILIZED TO THE SATISFACTION OF THE RELEVANT AGENCIES, THE CLIENT AND OR THE SITE ENGINEER.
8. ALL SITE RESTORATION TO BE IN ACCORDANCE WITH THE LANDSCAPE REHABILITATION PLANS AND DETAILS.
9. THE CONTRACTOR IS TO PROVIDE CITY OF MISSISSAUGA WITH 7 DAYS ADVANCE NOTICE PRIOR TO INITIATION OF CONSTRUCTION.
10. THE CONTRACTOR IS RESPONSIBLE FOR REMOVAL AND DISPOSAL OF ALL DEBRIS.
11. ALL SEDIMENTS AND EROSION CONTROL MEASURES SHALL BE INSPECTED DAILY TO ENSURE THAT THEY ARE FUNCTIONING PROPERLY AND ARE MAINTAINED AND/OR UPGRADED AS REQUIRED

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RE - ISSUED FOR TENDER	PT	12/20/2011
ISSUED FOR TENDER	PT	06/09/2011

Aquafor Beech Limited
#6-202-2600 SKYMARK Ave, MISSISSAUGA, ONTARIO, L4W 5B2
PHONE: (905) 629-0099, FAX: (905) 629-0089

MISSISSAUGA
Leading today for tomorrow

FIRST & THIRD STREET RECONSTRUCTION

PROJECT No.: 10128

DETAILS

DESIGNED BY: | APPROVED BY: P. K. TEIXEIRA | DRAWN BY: CR/JH | DATE: (MM.DD.YY) 12.20.11 | SCALE: HOR.- 1:100 VER.- 1:50 | SHEET No. 6 | DWG. No. SD-1

C48717

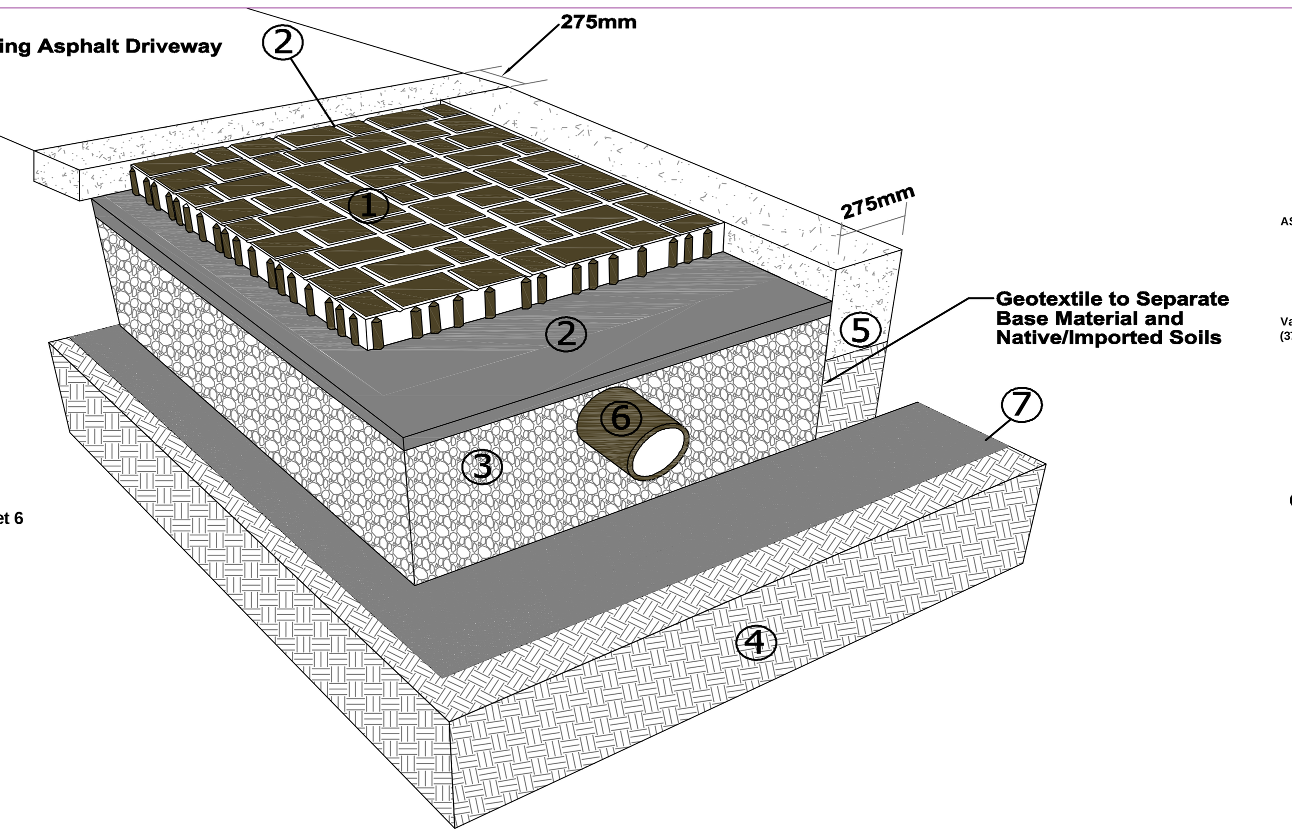
PERMEABLE PAVEMENT COMPONENT NOTES:

1. Paver - Must Conform to ASTM C396 Standard Specification for Solid Interlocking Paving Units or CAN3-A231.2 Standard Specification for Precast Concrete Pavers
   - A. Average compressive strength 8000 psi (55MPa) with no individual unit under 7,250 psi (50MPa) in accordance with ASTM C396 or CAN3-A231.2-M85.
   - B. Average absorption of 5% with no unit greater than 7% when tested according to ASTM C 140.
   - C. Resistance to 50 freeze-thaw cycles, when tested according to ASTM C 67 or CAN3-A231.2-M85, with no breakage greater than 1.0% loss in dry weight of any individual unit. This test method shall be conducted not more than 12 months prior to delivery.
   - D. Pigment in concrete pavers shall conform to ASTM C 979. ACI Report No. 212.3R provides guidance on the use of pigments.
   - E. Maximum allowable breakage of product is 5%.
2. Joint Aggregate - Crushed, Washed, Angular Chip Stone in Accordance with the Requirements of ASTM D 33 No.8 (5-6mmØ Stone). Commonly Referred to as HPB™(High Performance Base).
3. Granular Base Aggregate - Crushed, Washed, Angular, Open Graded Stone Conforming to ASTM C 33 No.57 (20mmØ Stone), Minimum Thickness of 100mm.
4. Native Material
5. Curb - See OPSD
   - When Curb and Gutter is Adjacent to Concrete pavement or Base, this Drawing is to be Used in Conjunction with Modified OPSD-600.020. See Detail Sheet 6
   - Pavers Shall be Placed 5mm above the Adjacent Edge of Gutter.
   - For Slipforming Procedure, a 5% Batter is Acceptable.
     - o Treatment at Entrances Shall Conform with City standards.
     - o Outlet treatment Shall Conform with OPSD-610 Series.
     - o The Length of Transition from one Curb Type to another Shall be 0.3m, or per City's Standards.
6. Underdrain - Perforated Pipe Constructed in Accordance with OPS 405. Minimum Pipe Diameter 200mm, 10mm Diameter perforations in Pipe. Note: Pipes Should Terminate 0.3m Short of the Sides of the Excavated Opening.
7. Geotextile Fabric - Non-woven 5-10mm Polyalkane Geotextile Recommended for Rapid Hydrocarbon Degradation.

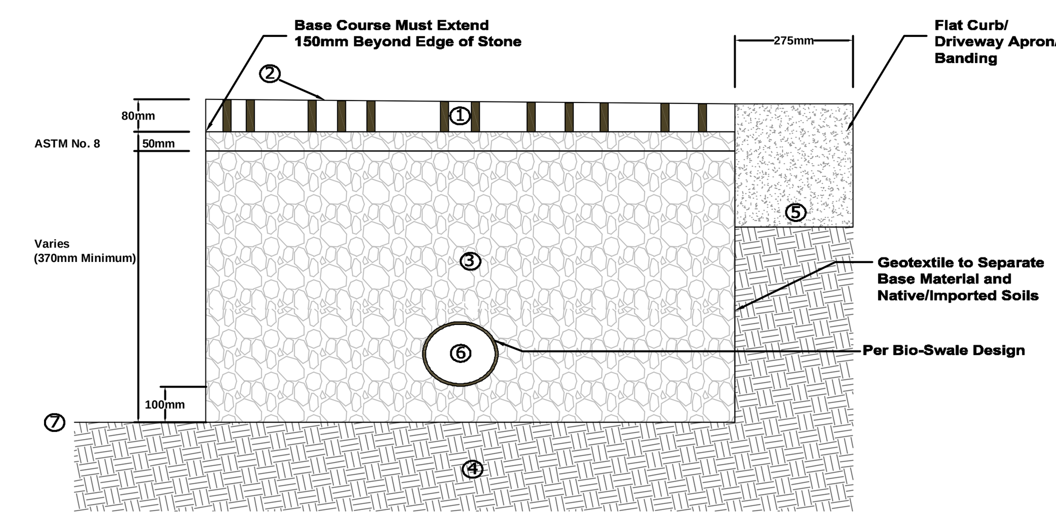
Grab Tensile Strength≥54.4 Kg
Mullen Burst Test ≥ 1.5 Mpa
Flow Rate ≥ 2.0m³/hr/m
UV Resistance after 500 hrs ≥70%
Heat-set or Heat-Calendared Fabrics are not Permitted.

Filler Fabric must conform to one of the following:
A) AOS (Apparent Opening Size) - maximum Avg. roll value < 0.3m for non-woven needle punched fabrics
OR
B) POA (Percent Open Area) > 4% for woven monofilament fabrics must also conform to OPSS 1860 for class II geotextile - fabrics that are 'woven silt film' or 'non-woven heat bonded fabrics' are unacceptable and shall not be used.

1 PERMEABLE INTERLOCKING CONCRETE PARKING LOT



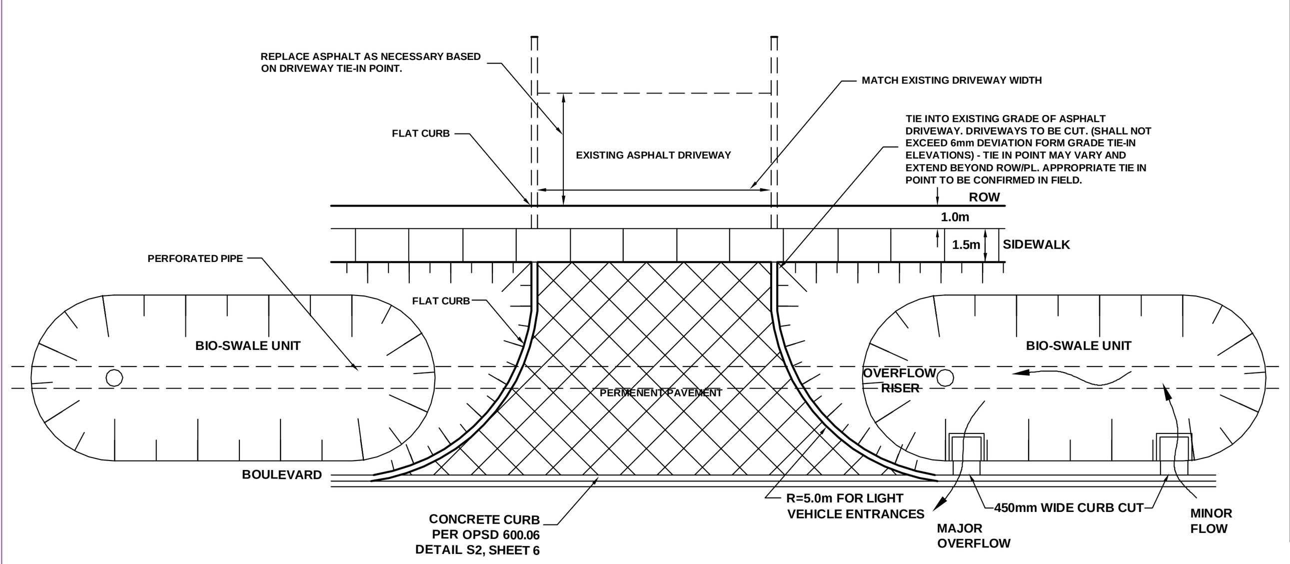
DETAIL PD1
PERMEABLE INTERLOCKING DRIVEWAY DETAIL
N.T.S.



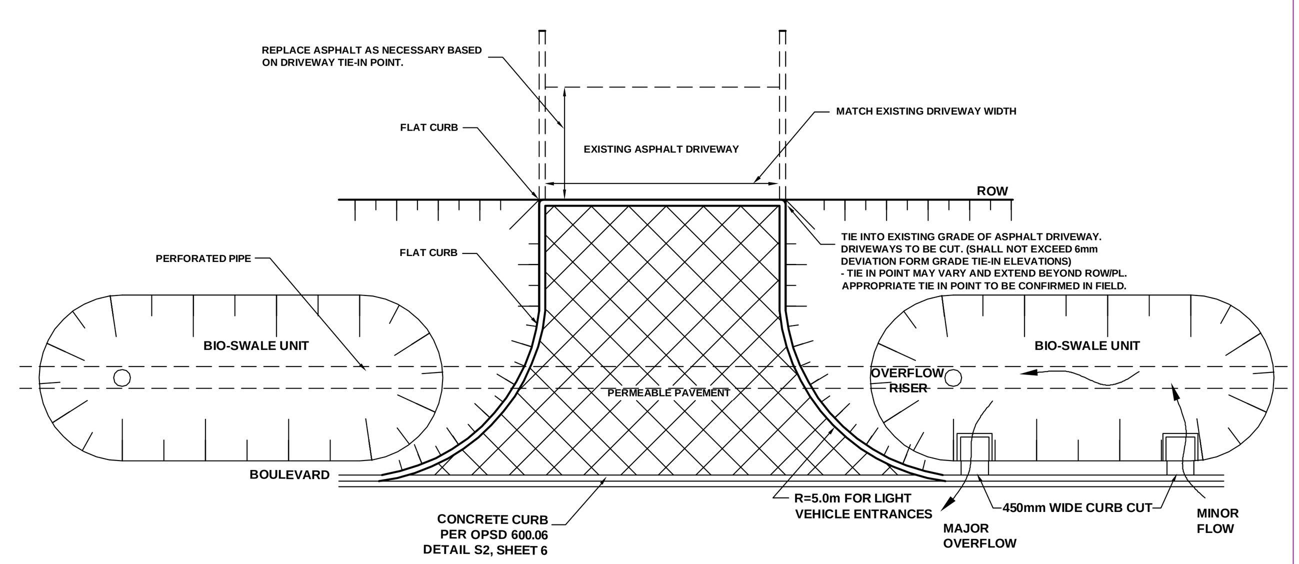
2 DRIVEWAY DETAIL NTS

GENERAL NOTES

- A Standpipe With Cap to be Installed From the Underdrain to the Pavement Surface for Monitoring and Maintenance of the Underdrain System.
- Aggregate Materials Used in the Construction of Permeable Pavements Shall Be Clean, Have Zero Plasticity and Contain no No. 200 Sieve Size Materials.
- Stone Aggregate Should Be Placed in 100mm to 150mm Lifts and Compacted with a Minimum 9,070 Kilograms (10 Ton) Steel Drum Roller. Stone Materials Should Be Moist During Compaction.
- Sediment Control Fencing to be Installed Prior to the Commencement of Construction to Prevent Runoff From Contaminating Excavated Surface of the Native Soils And or the Aggregate Base Courses.
- Final Grade of the Permeable Pavement Subbase to be Excavated Immediately Prior to Backfilling With Specified Base Course to Avoid Premature Facility Clogging.
- All Construction Materials are to be Stored Down-Gradient of Excavated Site Whenever Possible. Materials Stored Up-Gradient of the Excavated Site are to be Enclosed By Appropriate Sediment Control Fencing.

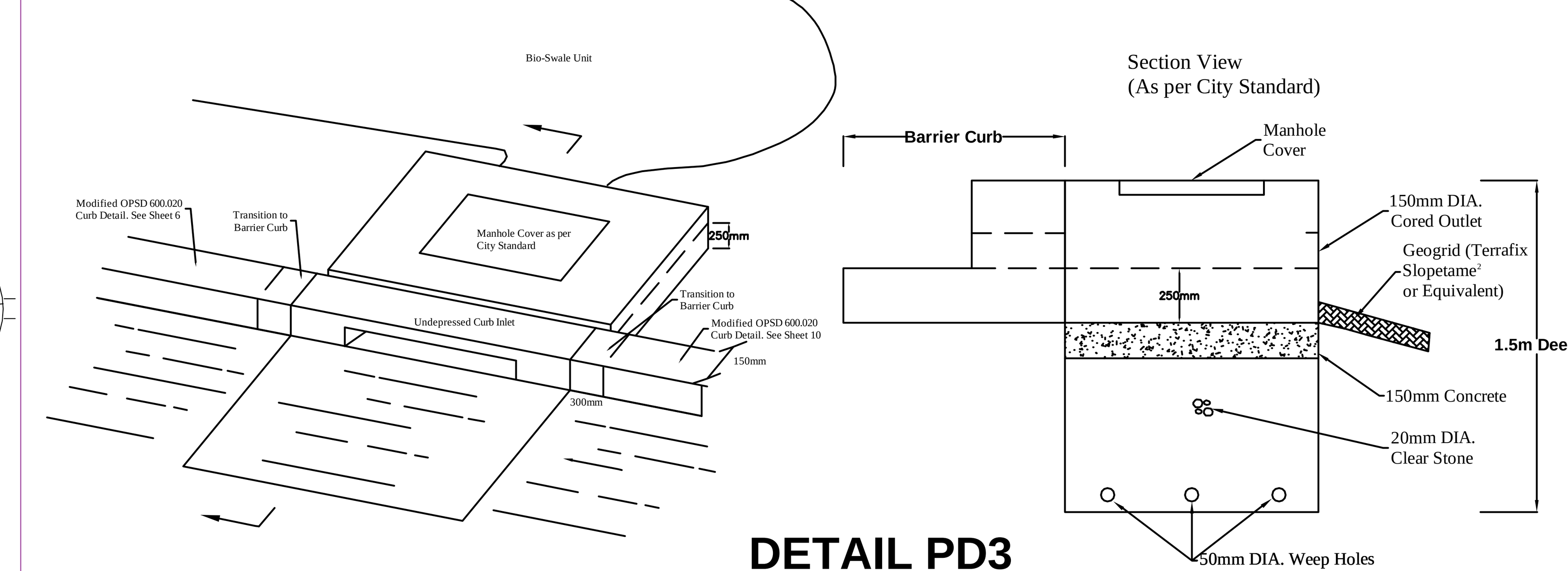


TYPICAL PERMEABLE PAVEMENT
PLAN VIEW
WITH SIDEWALK



TYPICAL PERMEABLE PAVEMENT
PLAN VIEW
WITHOUT SIDEWALK

DETAIL PD2
TYPICAL PERMEABLE PAVEMENT DETAIL
N.T.S.



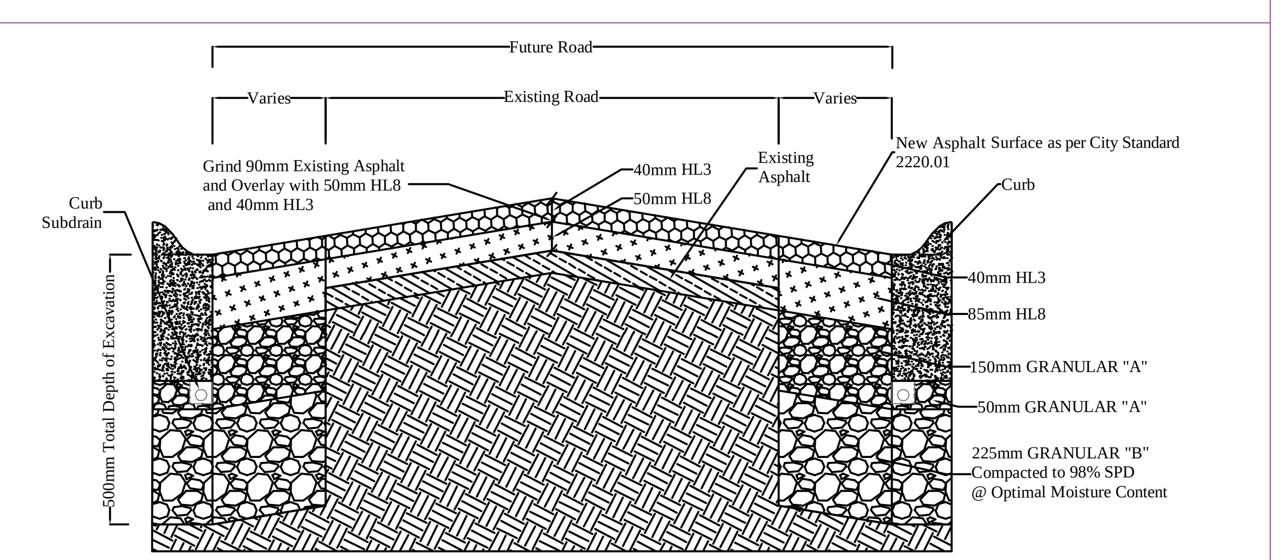
DETAIL PD3
SIDE INLET CATCH BASIN DETAIL (N.T.S.)

BIO-SWALE & ESC NOTES

1. DURING CONSTRUCTION, PROVISIONS SHALL BE MADE FOR PROPER WATER MANAGEMENT AND DRAINAGE OF THE SITE. THIS SHALL INCLUDE SILT TRAPS, ALL EROSION CONTROL MEASURES, TEMPORARY WATER COLLECTION DITCHES AND OVERFLOW STRUCTURE, AS WELL AS THE PROPER MAINTENANCE OF SUCH THROUGHOUT THE CONSTRUCTION PERIOD. AT NO TIME SHALL SEDIMENT LADEN WATER BE ALLOWED TO ENTER THE EXCAVATED/BACKFILLED OR COMPLETED BIOSWALE AREA. PRIOR TO THE STABILIZATION OF THE PLANTING MATERIAL/ BIOSWALE FACILITY, NO SITE DRAINAGE AND/OR STORM DRAINAGE IS TO ENTER THE PROPOSED BIOSWALE AREA. SHOULD SEDIMENT ENTER THE FACILITY PRIOR TO RECEIVING APPROVAL FROM FIELD ENGINEER/ LANDSCAPE ARCHITECT, THE INFILTRATION RATE OF THE CONTAMINATED AREA SHOULD BE TESTED USING THE GUELPH PERMEAMETER TEST TO CONFIRM NO LOSS IN INFILTRATION POTENTIAL. SHOULD A LOSS OF INFILTRATION CAPACITY BE CONFIRMED, THE CONTRACTOR WILL BE RESPONSIBLE FOR THE REPAIR/ REMEDIATION OF THE CONTAMINATED AREA TO THE SATISFACTION OF THE CLIENT/ ENGINEER/ LANDSCAPE ARCHITECT, USING APPROVED MEASURES/ MATERIALS AND PRACTICES.
2. ADHERENCE TO CONSTRUCTION SEQUENCING IS REQUIRED AS PART OF THE ESC PLAN. CONSTRUCTION SEQUENCING IS AN INTEGRAL COMPONENT OF ESC PROCEDURES/ PRACTICES AND HAS BEEN DESIGNED IN ORDER TO ENSURE THAT NO CONTAMINATION/ REDUCTION IN INFILTRATION CAPACITY TAKES PLACE AS A RESULT OF CONSTRUCTION ACTIVITIES.
3. TEMPORARY SEDIMENT CONTROLS TO BE INSTALLED PRIOR TO THE START OF CONSTRUCTION.
4. SEDIMENT CONTROL FOR THE CURB CUTS SHALL CONSIST OF WOODED BARRIER INSTALLED ALONG CURB-CUT OPENING TO PREVENT FLOWS FROM ENTERING THE BIOSWALE FACILITIES. THE WOODEN BARRIER SHALL BE STALKED SECURELY IN PLACE ON THE BACKSIDE OF THE PROPOSED CURBS. FILTER CLOTH SHALL BE PLACED BETWEEN THE CURB AND THE WOODEN BARRIER TO PREVENT SEDIMENT FROM BYPASSING THE WOODEN BARRIERS VIA CRACKS OR SMALL OPENINGS. BARRIER MATERIALS SHALL BE APPROVED BY THE FIELD ENGINEER PRIOR TO INSTALLATION.
5. IF REQUIRED BY THE FIELD ENGINEER, THE CONTRACTOR SHALL PLACE SEDIMENT LOGS/SOCKS AT CURB-CUT LOCATIONS AND ENTRY POINTS TO THE BIOSWALES TO PREVENT SEDIMENT ENTRY INTO THE PROPOSED BIOSWALE FACILITIES.
6. SEDIMENT LOG/SOCKS, OR APPROVED EQUIVALENT SHALL BE INSTALLED AT PROPOSED SIDE INLET CATCH BASINS PRIOR TO BIOSWALE CONSTRUCTION TO PREVENT SEDIMENT ENTRY INTO BIOSWALE FACILITIES.
7. CONTRACTOR IS RESPONSIBLE FOR ANY REMEDIATION/REPAIR OF INFILTRATION FACILITIES DAMAGED AS A RESULT OF INADEQUATE OR IMPROPER SEDIMENT CONTROL.
8. THE CONTRACTOR SHALL DELINEATE THE REQUIRED WORKING AREA ON-SITE PRIOR TO THE START OF WORK AND SHALL CONFINE OPERATIONS WITHIN THE DEFINED AREA.
9. TEMPORARY TOPSOIL AND/OR FILL MATERIAL STOCKPILE AREAS TO BE ENCLOSED WITH SILTATION CONTROL FENCE. MATERIALS ARE NOT TO BE STOCKPILED UPSTREAM OF PROPOSED FACILITY.
10. LOCATION OF STOCKPILE AREAS TO BE DETERMINED ON-SITE PRIOR TO CONSTRUCTION AND APPROVED BY THE ENGINEER.
11. WORKING AREAS, ACCESS REQUIREMENTS, AND TEMPORARY MATERIAL STORAGE AREAS TO BE MAINTAINED IN GOOD CONDITION BY THE CONTRACTOR AT ALL TIMES. AREAS AFFECTED BY THE CONTRACTOR'S ACTIVITIES TO BE REINSTATED TO THE EXISTING CONDITIONS OR BETTER.
12. NO RUNOFF FROM EXCAVATED OR UNVEGETATED AREAS SHALL BE DISCHARGED OFF SITE INTO ACTIVE AND/OR INACTIVE STORM SEWERS OR WATERCOURSES.
13. ALL ACCUMULATED SEDIMENTS TO BE REMOVED PRIOR TO THE REMOVAL OF CONTROLS AND DISPOSED OF IN AN APPROVED ON-SITE LOCATION BY THE CONTRACTOR (LOCATION TO BE DETERMINED IN THE FIELD).
14. ON-SITE EQUIPMENT REFUELING AND MAINTENANCE TO BE ONLY COMPLETED IN DESIGNATED AREAS.
15. SEDIMENT CONTROLS TO BE INSPECTED WEEKLY AND AFTER EACH RAINFALL EVENT. SEDIMENT CONTROLS TO BE MAINTAINED AND REPAIRED BY THE CONTRACTOR UNTIL COMPLETION OF CONSTRUCTION AND SITE RESTORATION.
16. ALL SITE RESTORATION TO BE IN ACCORDANCE WITH THE LANDSCAPE REHABILITATION PLAN AND DETAILS.
17. ALL ROADWAYS TO BE CLEANED OF SEDIMENTS RESULTING FROM CONSTRUCTION TRAFFIC FROM THE SITE EACH DAY.
18. EROSION PROTECTION TO BE PROVIDED AROUND ALL EXISTING STORM AND SANITARY MHs , DICBs AND CBs PRIOR TO CONSTRUCTION.
19. REMOVE TEMPORARY SEDIMENT CONTROLS FOLLOWING COMPLETION OF CONSTRUCTION AND SITE RESTORATION, AND REINSTATE AFFECTED AREAS TO EXISTING CONDITIONS OR BETTER.

UNDERDRAIN/ PERFORATED PIPE NOTES

1. UNDERDRAIN PERFORATED PIPE TO BE CONSTRUCTED IN ACCORDANCE WITH OPS 405. MINIMUM PIPE DIAMETER 200mm, 10mm DIAMETER PERFORATIONS IN PIPE.
   NOTE: PIPES SHOULD TERMINATE 0.3m SHORT OF THE ENDS OF THE EXCAVATED OPENING. ENDS TO BE CAPPED.
2. UNDERDRAIN MATERIAL SHOULD BE RESISTANT TO THE CHEMICALS PRESENT IN SOILS AND GROUNDWATER AND SHALL PROVIDE PROTECTION AGAINST DEGRADATION BY ULTRA - VIOLET LIGHT.
3. TUBING MUST BE UNIFORM IN COLOUR AND DENSITY AND FREE FROM VISIBLE DEFECTS
4. PERFORATED PIPE - WATER OPENING AREA SHALL NOT BE LESS THAN 16cm^2/m OF TUBING. WATER OPENING SHOULD BE LOCATED IN THE BOTTOM OF EXTERIOR CORRUGATION VALLEYS
5. THE TUBING SHALL HAVE A STIFFNESS OF NO LESS THAN 170kN//m^2 AT 5% DEFLECTION AND 130kN/m^2 AT 10% DEFLECTION WHEN TESTED IN ACCORDANCE WITH ASTM D2412.
6. DRAINAGE PIPES SHALL BE INSTALLED WITH CONSTANT GRADES TO DRAIN, HAVE SMOOTH TRANSITIONS AND ALL APPROPRIATE FITTINGS ACCORDING TO MANUFACTURER'S SPECIFICATIONS. CLEANOUT RISERS SHALL BE INSTALLED WHERE JUNCTIONS, GRADE OR DIRECTION CHANGES MAY CAUSE SILTATION WITHIN THE DRAIN LINES. MINIMUM SLOPE FOR UNDERDRAINS SHALL BE 0.5%.
7. PIPES SHALL BE LAID IN A TRUE LINE AND GRADIENT ON A FIRM BED, FREE FROM LOOSE MATERIAL. PIPES ARE NOT TO BE LAID ON SOIL BACKFILL OR IN A SLURRY AND ARE TO BE SECURELY POSITIONED TO AVOID DISPLACEMENT BEFORE BACKFILLING
8. THE INSIDE OF THE UNDERDRAIN SHALL BE KEPT CLEAN AND FREE OF DEBRIS DURING CONSTRUCTION. ALL DEBRIS SHOULD BE REMOVED BEFORE ADDITIONAL PIPE IS INSTALLED.
9. AGGREGATE BACKFILL MATERIAL SHALL BE FREE FROM FROZEN SNOW, ICE, FROZEN MATERIALS, TRASH, BRICK, CLAY LUMPS, BROKEN CONCRETE, TREE ROOTS, SOD, ASHES, GLASS PLASTER, VEGETABLE MATTER AND ANY OTHER FOREIGN MATTER.
10. UNDERDRAIN PIPES ARE TO BE JOINED USING APPROPRIATE FITTINGS AS PER PIPE MANUFACTURER SPECIFICATIONS.



DETAIL PD4
TYPICAL ROAD CROSS-SECTION DETAIL (N.T.S.)

PERMEABLE PAVEMENT NOTES:

GENERAL NOTES
Aggregate Materials Used in the Construction of Permeable Pavements Shall Be Clean, Have Zero Plasticity and Contain No No. 200 Sieve Size Materials. CRUSHED STONE SHALL BE 90% FRACTURED FACE, L.A. ABRASION ASTM C131, MINIMUM CBR OF 80S PER ASTM D 1883. SHOULD BE CLEAN WASHED; NO FINES SHOULD BE PRESENT IN MATERIAL (LESS THAN 1% PASSING 0.075MM SIEVE).

- Open-graded base
  1. Moisten, spread and compact the No. 57 base layer in one 100 mm thick lift. On this layer, make at least two passes in the vibratory mode then at least two in the static mode with a minimum 10 t (10 T) vibratory roller until there is no visible movement of the stone. Do not crush aggregate with the roller
  2. The surface tolerance of the compacted No. 57 subbase shall be ± 65 mm over a 3 m straightedge.
- Bedding layer
  1. Moisten, spread and screed the No. 8 stone bedding material.
  2. Fill voids left by removed screed rails with No. 8 stone.
  3. The surface tolerance of the screeded No. 8 bedding layer shall be ± 10 mm over a 3 m straightedge.
  4. Do not subject screeded bedding material to any pedestrian or vehicular traffic before paving unit installation begins.
- Permeable interlocking concrete pavers and joint/opening fill material
  1. Lay the paving units in the pattern(s) and joint widths shown on the drawings. Maintain straight pattern lines.
  2. Fill gaps at the edges of the paved area with cut units. Cut pavers subject to tire traffic shall be no smaller than 1/3 of a whole unit.
  3. Cut pavers and place along the edges with a masonry saw.
  4. Fill the openings and joints with [No. 8] stone.
     Note: Some paver joint widths may be narrow and not accept most of the No. 8 stone. Use joint material that will fill joints such as washed ASTM No. 9 or No. 10 stone.
  5. Remove excess aggregate on the surface by sweeping pavers clean.
  6. Compact and seat the pavers into the bedding material using a low-amplitude, 75-90 Hz plate compactor capable of at least 22 kN centrifugal compaction force. This will require at least two passes with the plate compactor.
  7. Do not compact within 2 m of the unrestrained edges of the paving units.
  8. Apply additional aggregate to the openings and joints if needed, filling them completely. Remove excess aggregate by sweeping then compact the pavers. This will require at least two passes with the plate compactor.
  9. All pavers within 2 m of the laying face must be left fully compacted at the completion of each day.
  10. The final surface tolerance of compacted pavers shall not deviate more than ± 10 mm under a 3 m long straightedge.
  11. The surface elevation of pavers shall be 3 to 6 mm above adjacent drainage inlets, concrete collars or channels.

JOINT/OPENING FILLER, BEDDING, BASE AND SUBBASE: CONFORMING TO ASTM D 448 GRADATIONS AS SHOWN IN TABLE 1, 2 AND 3 BELOW.

TABLE 1

ASTM NO. 8 GRADING REQUIREMENTS - BEDDING AND JOINT/OPENING FILLER	
SIEVE SIZE	PERCENT PASSING
12.5mm	100
9.5mm	85 to 100
4.75mm	10 to 30
2.36mm	0 to 10
1.16mm	0 to 5

TABLE 2

ASTM NO. 57 BASE GRADING REQUIREMENTS	
SIEVE SIZE	PERCENT PASSING
37.5mm	100
25mm	95 to 100
12.5mm	25 to 60
4.75mm	0 to 10
2.36mm	0 to 5

TABLE 3

ASTM NO. 2 SUB-BASE GRADING REQUIREMENTS	
SIEVE SIZE	PERCENT PASSING
75mm	100
63mm	90 to 100
50mm	35 to 70
37.5mm	0 to 15
19mm	0 to 5

GRADATION CRITERIA FOR BEDDING AND BASE:
D15 BASE STONE / D15 BEDDING STONE <5
D50 BASE STONE / D50 BEDDING STONE >2

Stone Aggregate Should Be Placed in 100mm to 150mm Lifts and Compacted with a Minimum 9,070 Kilograms (10 Ton) Steel Drum Roller. Stone Materials Should Be Moist During Compaction.

Sediment Control Fencing to be Installed Prior to the Commencement of Construction to Prevent Runoff From Contaminating Excavated Surface of the Native Soils and or the Aggregate Base Courses.

Final Grade of the Permeable Pavement Subbase to be Excavated Immediately Prior to Backfilling With Specified Base Course to Avoid Premature Facility Clogging.

All Construction Materials are to be Stored Down-Gradient of Excavated Site Whenever Possible. Materials Stored Up-Gradient of the Excavated Site are to be Enclosed By Appropriate Sediment Control Fencing.

FIELD QUALITY CONTROL
A. After sweeping the surface clean, check final elevations for conformance to the drawings.
B. Lippage: No greater than 3 mm difference in height between adjacent pavers.

Note: The surface of the pavers may be 3 to 6 mm above the final elevations after compaction. This helps compensate for possible minor settling normal to pavements.

C. The surface elevation of pavers shall be 3 to 6 mm above adjacent drainage inlets, concrete collars or channels.
D. Bond lines for paver courses: ±15 mm over a 15 m string line.

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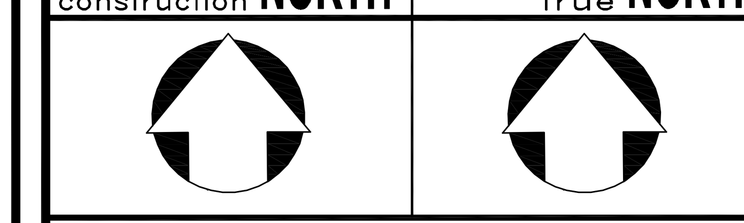

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BEFORE STARTING WORK

THE CONTRACTOR SHALL CONFIRM THE POSITION AND EXACT LOCATION OF ALL SUCH UTILITIES, AND SHALL ASSUME ALL LIABILITY FOR ANY DAMAGE TO THEM MADE DURING THE COURSE OF THE CONTRACT WORK.

NOTES:

LEGEND

- CROSS - SECTION # / LOCATION SHEET #
- PROPERTY/ BUILDING LINE
- EXISTING TREE
- BIO-SWALE UNIT
- FLOW DIRECTION
- SEDIMENT LOGS
- CURB CUT
- EXISTING FENCE/HEDGE
- EXISTING TREE TO BE REMOVED
- PERFORATED PIPE
- SOLID PIPE
- OVERFLOW RISER

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6. EROSION AND SEDIMENT CONTROL MEASURES (AND TREE/SHRUB PROTECTION BARRIERS) WILL BE IMPLEMENTED PRIOR TO AND MAINTAINED DURING THE CONSTRUCTION PHASES TO PREVENT ENTRY OF SEDIMENT INTO ANY FUTURE BIOSWALE OR PERMEABLE PAVEMENT FACILITY. THESE EROSION AND SEDIMENT CONTROL MEASURES WILL BE REMOVED FOLLOWING CONSTRUCTION COMPLETION AND WHEN DISTURBED AREAS HAVE BEEN STABILIZED AND VEGETATION ESTABLISHED.
7. ALL AREAS WHICH REMAIN DISTURBED FOR MORE THAN 30 DAYS MUST BE STABILIZED TO THE SATISFACTION OF THE RELEVANT AGENCIES, THE CLIENT AND OR THE SITE ENGINEER.
8. ALL SITE RESTORATION TO BE IN ACCORDANCE WITH THE LANDSCAPE REHABILITATION PLANS AND DETAILS.
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RE - ISSUED FOR TENDER	PT	12/20/2011
ISSUED FOR TENDER	PT	06/09/2011
REVISION	By	MM/DD/YY

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#6-202-2600 SKYMARK Ave,
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MISSISSAUGA
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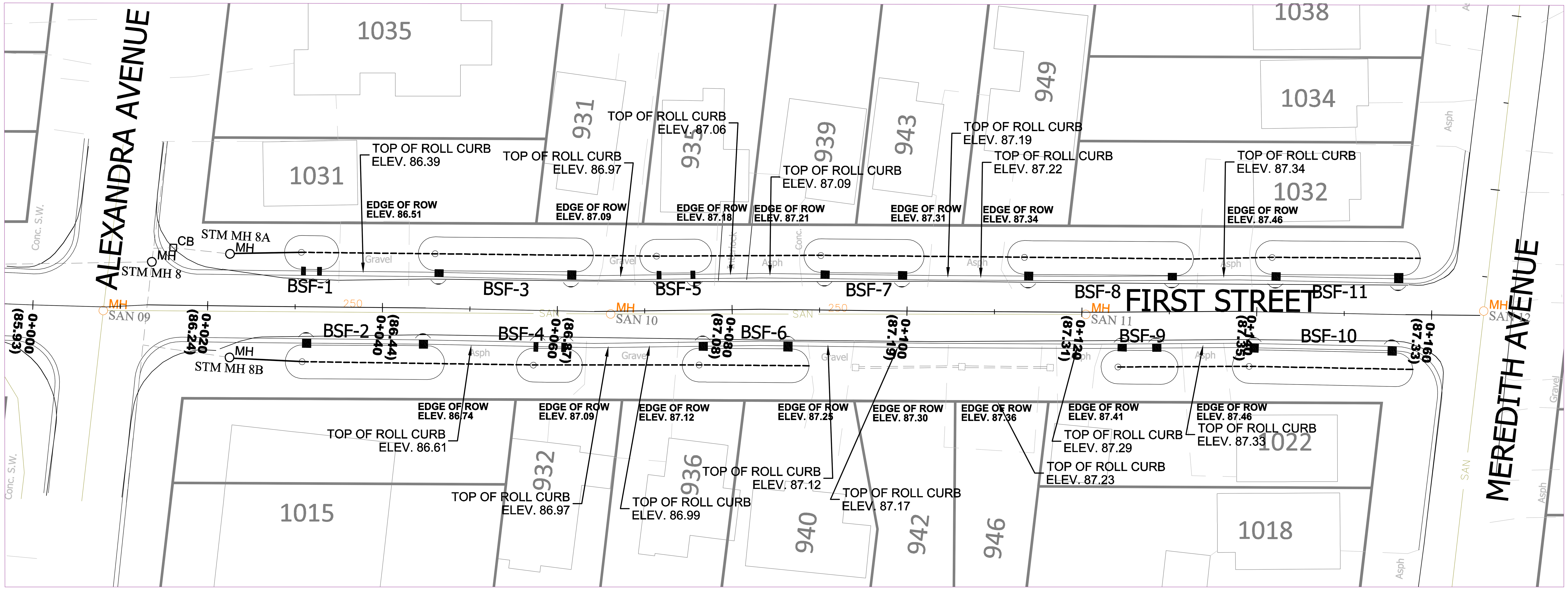
FIRST & THIRD STREET RECONSTRUCTION

PROJECT No.: 10128

PERMEABLE PAVEMENT DETAILS

DESIGNED BY:	APPROVED BY:	DRAWN BY: CR/JH
	P. K. TODD	DATE: (MM.DD.YY) 12.20.11
		SCALE: HOR.-1:100 VER.- 1:50
		SHEET No. 7
C48718		DWG. No. PD-1



FIRST STREET

TABLE 1 BIO-SWALE DETAILS

FIRST STREET

Bio-Swale ID	Length (m)	Start Station	Start Elevation	Stop Station	Stop Elevation	Overflow Station	Overflow Elevation
BSF-1	6.3	0+035.0	86.2	0+028.7	86.2	0+030.6	86.29
BSF-2	18.3	0+047.2	86.2	0+028.9	86.2	0+030.9	86.29
BSF-3	20.0	0+064.0	86.7	0+044.0	86.4	0+045.9	86.51
BSF-4	7.5	0+063.0	86.6	0+055.5	86.6	0+057.4	86.78
BSF-5	8.2	0+077.8	86.9	0+069.6	86.9	0+071.4	87.00
BSF-6	14.6	0+088.8	86.9	0+074.2	86.9	0+076.0	87.03
BSF-7	14.0	0+102.0	87.0	0+088.0	87.0	0+090.0	87.11
BSF-8	21.4	0+132.8	87.2	0+111.4	87.2	0+113.3	87.24
BSF-9	9.0	0+131.0	87.2	0+122.0	87.2	0+124.0	87.31
BSF-10	21.0	0+158.0	87.1	0+137.0	87.1	0+139.2	87.33
BSF-11	18.9	0+158.6	87.2	0+139.7	87.2	0+141.6	87.33

START ELEVATION = CORRESPONDS TO UPSTREAM EXTENT OF FINISHED GRADE OF BIOSWALE INVERT
STOP ELEVATION = CORRESPONDS TO DOWNSTREAM EXTENT OF FINISHED GRADE OF BIOSWALE INVERT

FLOW — START ELEVATION — STOP ELEVATION — FLOW

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- FLOW DIRECTION
- SEDIMENT LOGS
- CURB CUT
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REVISION	By	MM/DD/YY
RE - ISSUED FOR TENDER	PT	12/20/2011
ISSUED FOR TENDER	PT	06/09/2011

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FIRST & THIRD STREET RECONSTRUCTION

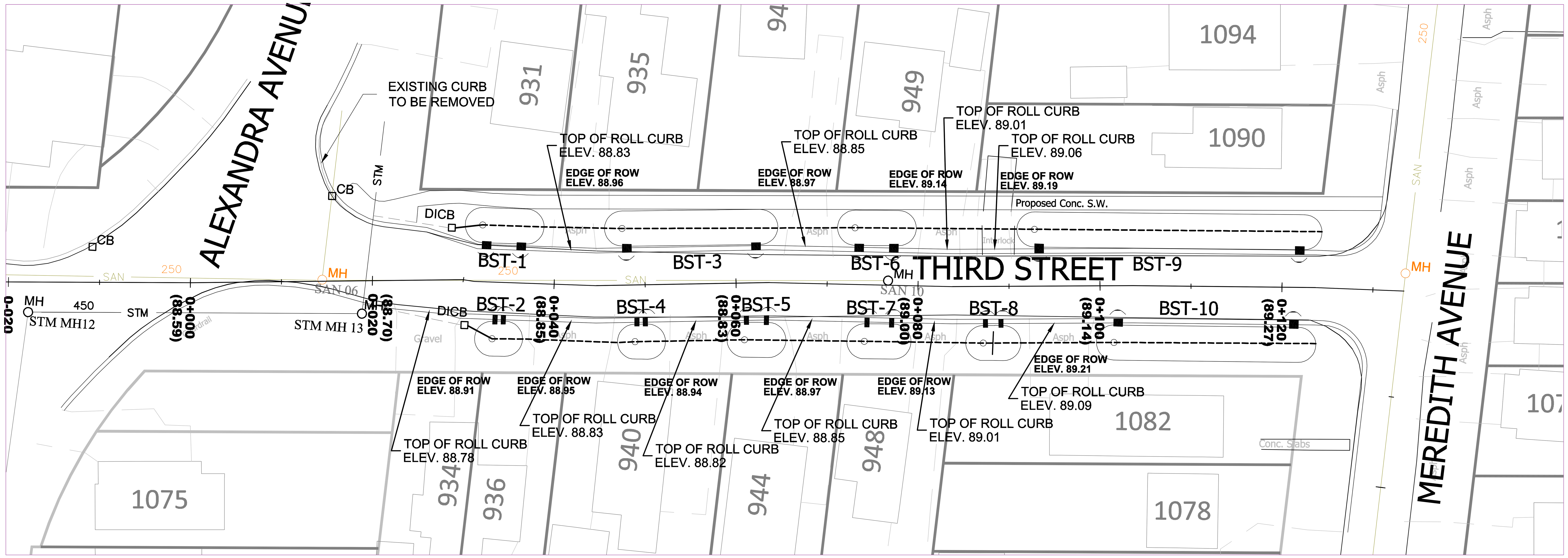
PROJECT No.: 10128

BIO-SWALE DETAILS FIRST STREET

FROM STA. 0+000 TO STA. 0+160

DESIGNED BY: | APPROVED BY: | DRAWN BY: CR/JH
DATE: (MM.DD.YY) 12.20.11
SCALE: HOR.-1:250
SHEET No. 8
DWG. No. BS-1

C48719



THIRD STREET

TABLE 2 BIO-SWALE DETAILS

THIRD STREET

Bio-Swale ID	Length (m)	Start Station	Start Elevation	Stop Station	Stop Elevation	Overflow Station	Overflow Elevation
BST-1	8.3	0+038.6	88.6	0+030.3	88.6	0+032.0	88.83
BST-2	5.2	0+036.7	88.7	0+031.5	88.7	0+033.3	88.83
BST-3	18.9	0+064.5	88.6	0+045.6	88.6	0+047.5	88.83
BST-4	5.3	0+052.1	88.6	0+046.8	88.6	0+048.7	88.83
BST-5	6.8	0+065.6	88.6	0+058.8	88.6	0+060.7	88.81
BST-6	8.6	0+079.6	88.8	0+071.0	88.8	0+073.0	88.91
BST-7	7.0	0+079.3	88.8	0+072.3	88.8	0+074.2	88.92
BST-8	6.1	0+091.3	88.9	0+085.2	88.9	0+087.1	89.04
BST-9	33.5	0+124.4	89.0	0+090.9	88.9	0+092.8	89.07
BST-10	24.2	0+123.7	89.1	0+099.5	88.9	0+101.5	89.13

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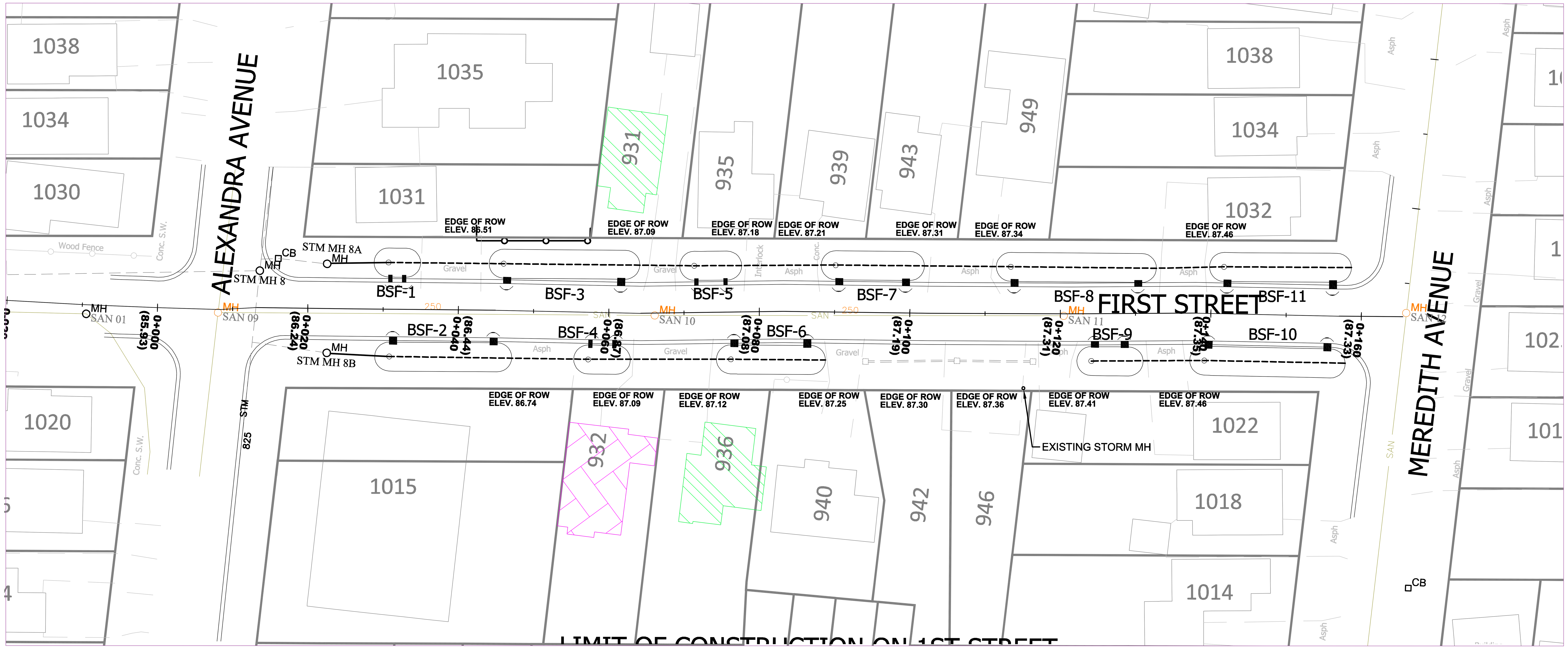
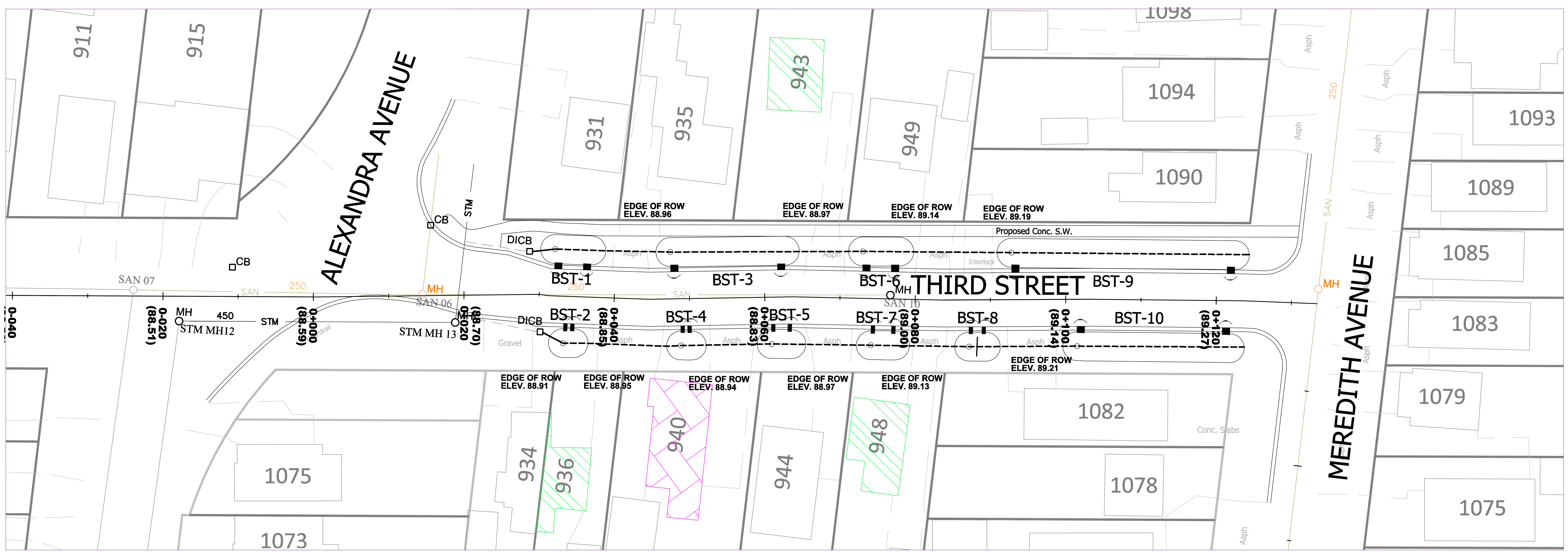
FIRST & THIRD STREET RECONSTRUCTION
PROJECT No.: 10128

BIO-SWALE DETAILS
THIRD STREET
FROM STA. 0+000 TO STA. 0+120

DESIGNED BY:	APPROVED BY:	DRAWN BY: CR/JH
	P. K. TEIXEIRA	DATE: (MM.DD.YY) 12.20.11
		SCALE: HOR.-1:250
		SHEET No. 9
C48720		DWG. No. BS-2



FIRST STREET



THIRD STREET

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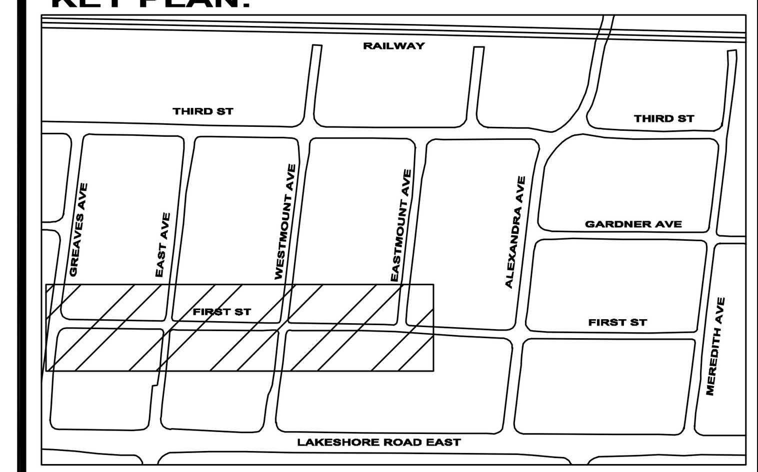

LEGEND

- CROSS - SECTION # / LOCATION SHEET #
- PROPERTY/ BUILDING LINE
- EXISTING TREE
- BIO-SWALE UNIT
- FLOW DIRECTION
- SEDIMENT LOGS
- CURB CUT
- EXISTING FENCE/HEDGE
- EXISTING TREE TO BE REMOVED
- PERFORATED PIPE
- SOLID PIPE
- OVERFLOW RISER
- PROVISIONAL FRENCH DRAIN REQUIRED ON CITY LAND
- PROVISIONAL FRENCH DRAIN REQUIRED ON PRIVATE PROPERTY

GENERAL NOTES:

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RE - ISSUED FOR TENDER	PT	12/20/2011
ISSUED FOR TENDER	PT	06/09/2011
REVISION	By	MM/DD/YY

Aquafor Beech Limited
#6-202-2600 SKYMARK Ave,
MISSISSAUGA, ONTARIO, L4W 5B2
PHONE: (905) 629-0099, FAX: (905) 629-0089

MISSISSAUGA
Leading today for tomorrow

FIRST & THIRD STREET RECONSTRUCTION

PROJECT No.: 10128

FRENCH DRAIN REQUIRED ON CITY LAND OR PRIVATE ROPERTY

FIRST & THIRD STREET

DESIGNED BY:

APPROVED BY: LICENSED PROFESSIONAL ENGINEER P. K. TEWARI PROVINCE OF ONTARIO

DRAWN BY: CR/JH

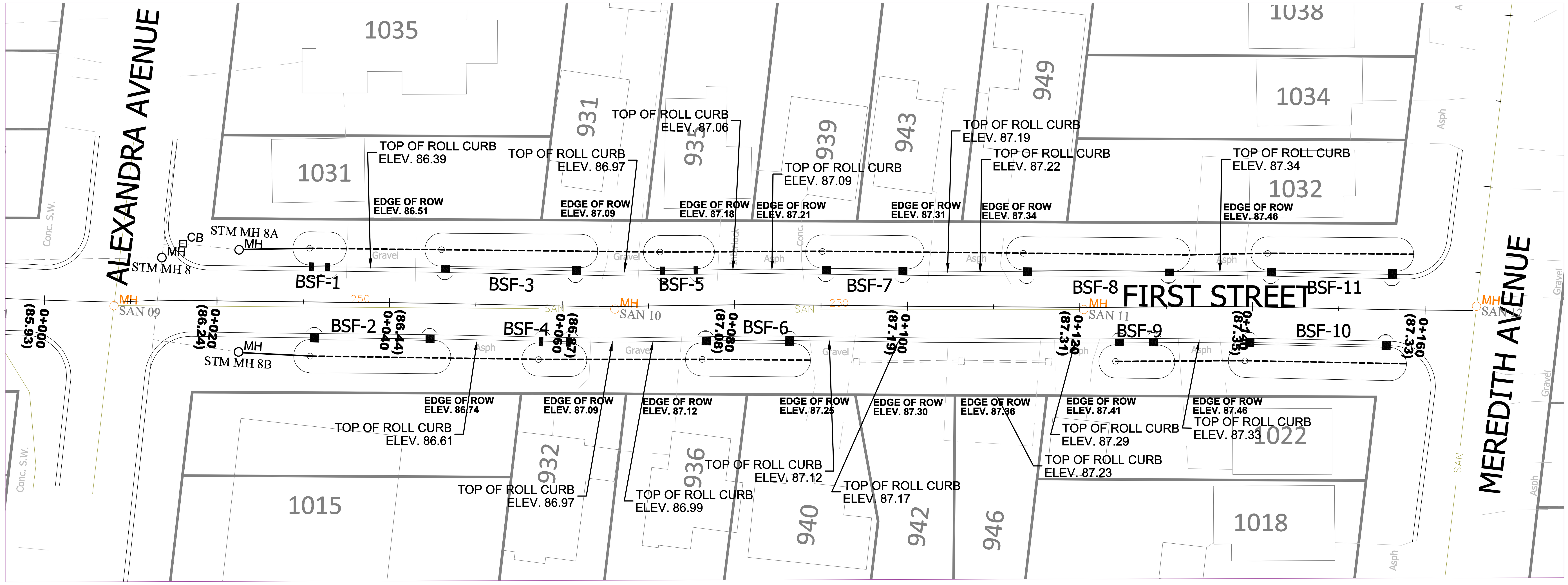
DATE: (MM.DD.YY) 12.20.11

SCALE: HOR.-1:300

SHEET No. 10

C48721

DWG. No. FD-1



FIRST STREET

TABLE 3 DRIVEWAY ELEVATIONS (TOP OF ROLL CURB & EDGE OF ROW)

FIRST STREET

House No.	Street Location	Driveway Location	Station	Top of Roll Curb Elevation	Edge of ROW Elevation
1031 Alexandra Ave	First Street North side	Between BSF 1 & 3	0+038.5	86.39	86.51
1015 Alexandra Ave	First Street South side	Between BSF 2 & 4	0+050.5	86.61	86.74
931 First Street	First Street North side	Between BSF 3 & 5	0+066.5	86.97	87.09
932 First Street	First Street South side	Between BSF 4 & 6	0+066.5	86.97	87.09
936 First Street	First Street South side	Between BSF 4 & 6	0+071.3	86.99	87.12
935 First Street	First Street North side	Between BSF 5 & 7	0+080.0	87.06	87.18
939 First Street	First Street North side	Between BSF 5 & 7	0+084.5	87.09	87.21
940 First Street	First Street South side	Between BSF 6 & 9	0+091.0	87.12	87.25
942 First Street	First Street South side	Between BSF 6 & 9	0+099.3	87.17	87.30
946 First Street	First Street South side	Between BSF 6 & 9	0+110.0	87.23	87.36
943 First Street	First Street North side	Between BSF 7 & 8	0+104.7	87.19	87.31
949 First Street	First Street North side	Between BSF 7 & 8	0+108.5	87.22	87.34
1022 Meredith Ave	First Street South side	Between BSF 6 & 9	0+120.0	87.29	87.41
1022 Meredith Ave	First Street South side	Between BSF 6 & 10	0+133.8	87.33	87.46
1032 Meredith Ave	First Street North side	Between BSF 8 & 11	0+136.5	87.34	87.46

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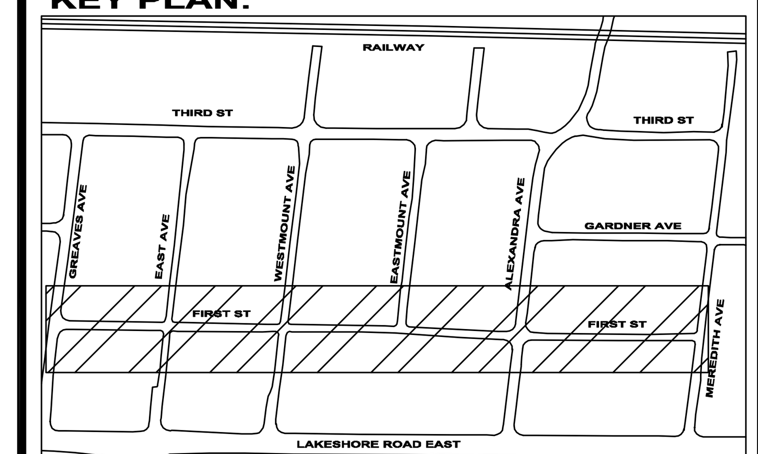

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MISSISSAUGA Leading today for tomorrow

FIRST & THIRD STREET RECONSTRUCTION

PROJECT No.: 10128

DRIVEWAY ELEVATION DETAILS

FIRST STREET

FROM STA. 0+000 TO STA. 0+160

DESIGNED BY: | APPROVED BY: | DRAWN BY: CR/JH

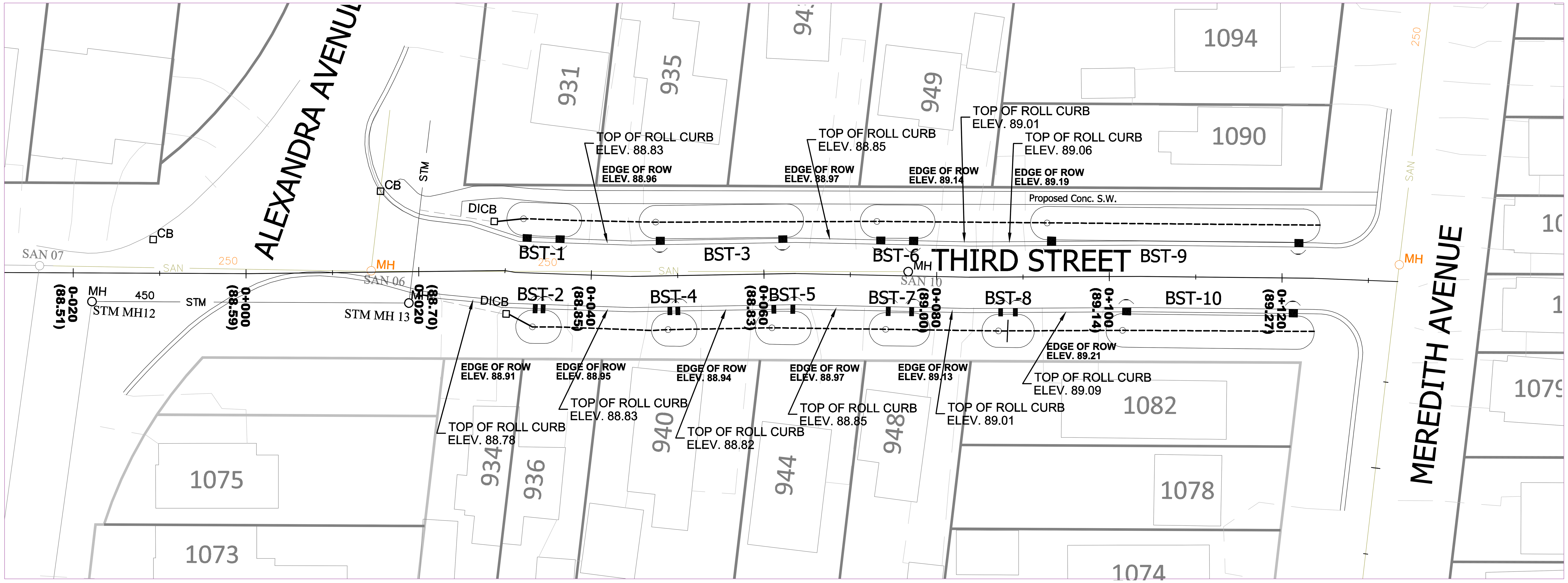
DATE: (MM.DD.YY) 12.20.11

SCALE: HOR.-1:500

SHEET No. 11

DWG. No. DE-1

C48722



THIRD STREET

TABLE 4 DRIVEWAY ELEVATIONS (TOP OF ROLL CURB & EDGE OF ROW)

THIRD STREET

House No.	Street Location	Driveway Location	Station	Top of Roll Curb Elevation	Edge of ROW Elevation
934 Third Street	Third Street South side	Between BST 2 & Park	0+026.1	88.78	88.91
936 Third Street	Third Street South side	Between BST 2 & 4	0+042.6	88.83	88.95
935 Third Street	Third Street North side	Between BST 1 & 3	0+071.5	88.83	88.96
940 Third Street	Third Street South side	Between BST 4 & 5	0+055.7	88.82	88.94
943 Third Street	Third Street North side	Between BST 3 & 6	0+067.7	88.85	88.97
948 Third Street	Third Street South side	Between BST 5 & 7	0+068.1	88.85	88.97
949 Third Street	Third Street North side	Between BST 6 & 9	0+082.3	89.01	89.14
1082 Meredith Ave	Third Street South side	Between BST 8 & 10	0+095.4	89.09	89.21
1090 Meredith Ave	Third Street North side	Between BST 6 & 9	0+088.3	89.06	89.19

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KEY PLAN:

LEGEND

CROSS - SECTION # / LOCATION SHEET #
PROPERTY/ BUILDING LINE
EXISTING TREE
BIO-SWALE UNIT
FLOW DIRECTION
SEDIMENT LOGS
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FIRST & THIRD STREET RECONSTRUCTION

PROJECT No.: 10128

DRIVEWAY ELEVATION DETAILS THIRD STREET

FROM STA. 0+000 TO STA. 0+120

DESIGNED BY:

APPROVED BY: P. K. TEGART (LICENSED PROFESSIONAL ENGINEER, PROVINCE OF ONTARIO)

DRAWN BY: CR/JH

DATE: (MM.DD.YY) 12.20.11

SCALE: HOR.-1:250

SHEET No. 12

C48723

DWG. No. DE-2

MISSISSAUGA

Leading today for tomorrow

FIRST STREET & THIRD STREET RECONSTRUCTION - PLANTING

CONTRACT No: 17 111 10128

Drawing Index

Description	Drawing No.
LANDSCAPE PLAN – 1 (1ST STREET)	LP–1
LANDSCAPE PLAN – 3 (3RD STREET)	LP–2
PARKETTE PLAN – 3 (3RD STREET)	LP–3
LANDSCAPE DETAILS	LD–1

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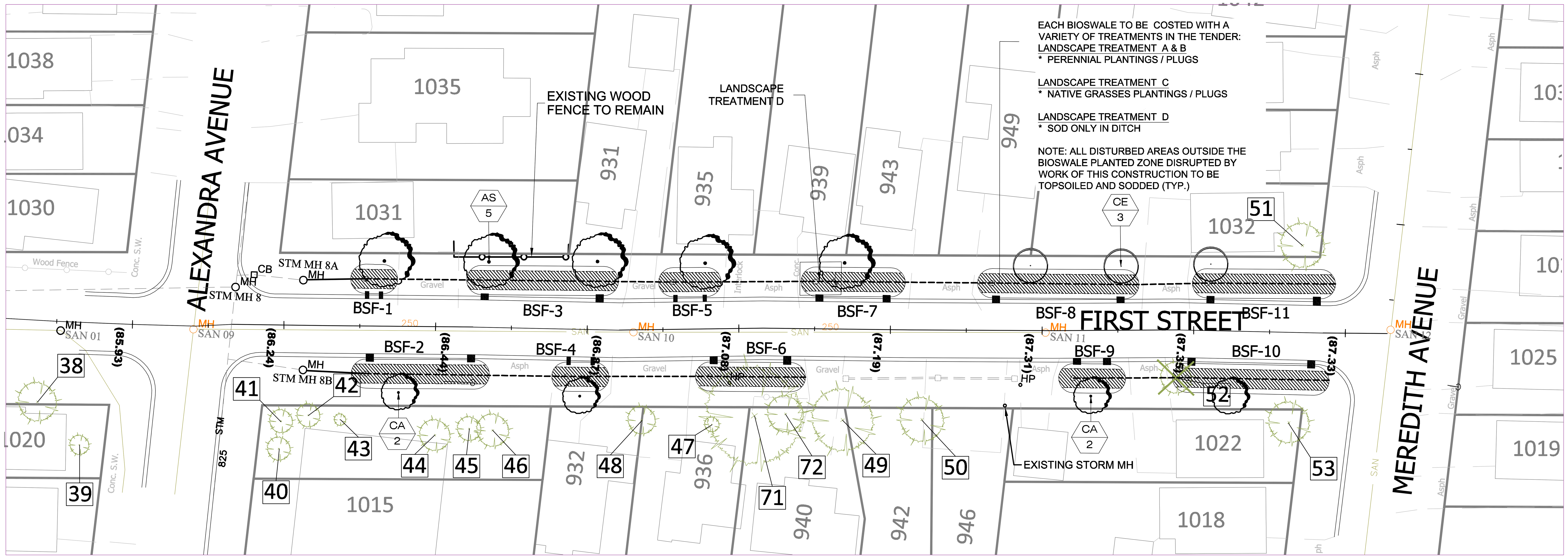

FIRST STREET

TREE INVENTORY AND ASSESSMENT:

Tree #	Species		Diameter (cm) Approx.	General Condition
	Species Common Name	Botanical Name		
40	Austrian Pine	*Pinus nigra*	30	Dead patches; Could eventually interfere with wire
41	Austrian Pine	*Pinus nigra*	30	Dead patches; Disturbing wire
42	Austrian Pine	*Pinus nigra*	30	Dead patches; Disturbing wire
43	White Ash	*Fraxinus americana*	15	Dead patches; Disturbing wire
44	Austrian Pine	*Pinus nigra*	40	Healthy; Disturbing wire
45	Austrian Pine	*Pinus nigra*	31	Healthy; Disturbing wire
46	Austrian Pine	*Pinus nigra*	42	Healthy; Disturbing wire
47	White Birch	*Betula papyrifera*	19	Healthy; Disturbing wire
48	Manitoba Maple	*Acer negundo*	36	Healthy
49	Silver Maple	*Acer saccharinum*	80	Healthy; Disturbing wire
50	Red Ash	*Fraxinus pennsylvanica*	57	Some dead patches in canopy
51	Red Ash	*Fraxinus pennsylvanica*	57	Healthy; Disturbing wire
52	White Pine	*Pinus strobus*	40	Healthy; Disturbing wire
53	Scots Pine	*Pinus sylvestris*	53	Die back at bottom; Disturbing wire

BIO-SWALE AREA AND PLANT QUANTITY

FIRST STREET LP-1 (Width 3.7 m, planting area width 2.5 m)											
BIO-SWALE AREA						FOUR ALTERNATIVE LANDSCAPE TREATMENT TO BE PRICED IN TENDER					
Bio-swale ID	Length (m)	Total Area (m2)	Planting Area (m2)	Quantity of Plugs (pc)	Sod Area within BS (m2)	Type A-Native Perennials (pc)		Type B-Native Perennials (pc)		Type C-Native Grasses (pc)	
						Zone 2	Zone 3	Zone 2	Zone 3	Zone 2	Zone 3
BSF-1	6.3	20.7	15.75	**157**	4.95	79	79	79	79	79	79
BSF-2	18.3	67	45.75	**457**	21.25	229	229	229	229	229	229
BSF-3	20	74	50	**500**	24	250	250	250	250	250	250
BSF-4	7.5	25.9	18.75	**187**	7.15	94	94	94	94	94	94
BSF-5	8.2	28.6	20.5	**205**	8.1	103	103	103	103	103	103
BSF-6	14.6	52.7	36.5	**365**	16.2	183	183	183	183	183	183
BSF-7	14	49.7	35	**350**	14.7	175	175	175	175	175	175
BSF-8	21.4	78.8	53.5	**535**	25.3	268	268	268	268	268	268
BSF-9	9	30.8	22.5	**225**	8.3	113	113	113	113	113	113
BSF-10	21	76.5	52.5	**525**	24	263	263	263	263	263	263
BSF-11	18.9	69.6	47.25	**472**	22.35	236	236	236	236	236	236
	Sub Total	574.3	398	**3978**	176.3	1989	1989	1989	1989	1989	1989

Landscape Treatment Type A-Native Perennials	Zone 2 (50% of planting area) 199 m2	1989 pcs	NOTES:	One specie per zone per plant list @ 0.3 mo/c
	Zone 3 (50% of planting area) 199 m2	1989pcs		One specie per zone per plant list @ 0.3 mo/c
Landscape Treatment Type B-Native Perennials	Zone 2 (50% of planting area) 199 m2	1989 pcs		One specie per zone per plant list @ 0.3 mo/c
	Zone 3 (50% of planting area) 199 m2	1989pcs		One specie per zone per plant list @ 0.3 mo/c
Landscape Treatment Type C-Native Grasses	Zone 2 (50% of planting area) 199 m2	1989 pcs		One specie per zone per plant list @ 0.3 mo/c
	Zone 3 (50% of planting area) 199 m2	1989pcs		One specie per zone per plant list @ 0.3 mo/c
Landscape Treatment Type D-Sodded Swale Only)	100% of planting area 398 m2			

NOTE: ONLY ONE OF THE 4 OPTIONS TREATMENTS A–D SHOWN ABOVE WILL APPLY TO EACH OF THE BIOSWALES, TYPICALLY 'A' OR 'B', BUT OPTION 'C' AND 'D' ARE ALSO HOMEOWNER OPTIONS TO BE CONFIRMED ON SITE

PLANT SCHEDULE

Proposed Street Tree Planting

Quan	Key	Botanical Name	Common Name	Size	Root	Comments
5	AS	*Acer saccharum*	Sugar Maple	60mm	WB	spacing as ind.
	AF	*Acer freemanni*	Freeman Maple	60mm	WB	
	AC	*Amelanchier canadensis*	Downy Serviceberry	50mm	WB	
	AL	*Amelanchier laevis*	Allegheny Serviceberry	50mm	WB	
4	CA	*Carpinus caroliniana*	Blue Beech	60mm	WB	
3	CE	*Cercis canadenis*	Eastern Redbud	50mm	WB	

Landscape Treatment Type A

Root: All plants to be plugs

Spacing: All plants to be spaced 0.3m on center

Seeding: All corresponding seed species to be spread in the applicable zone

Perennial Planting

P-2/Zone 2 - Drought Tolerant Species

Quan	Key	Botanical Name	Common Name	Seed
1989	P2-1	*Rudbeckia hirta*	Black Eyed Susan	✓

P-3/Zone 3 - Moist/Wet Soils Species

Quan	Key	Botanical Name	Common Name	Seed
1989	P3-1	*Penstemon digitalis*	Foxglove Beardtongue	✓

Landscape Treatment Type B

Perennial Planting

P-2/Zone 2 - Drought Tolerant Species

Quan	Key	Botanical Name	Common Name	Seed
1989	P2-1	*Liatris spicata*	Dense Blazing Star	✓

P-3/Zone 3 - Moist/Wet Soils Species

Quan	Key	Botanical Name	Common Name	Seed
1989	P3-1	*Helenium autumnale*	Sneezeweed	✓

Landscape Treatment Type C

Native Grass Planting

G-2/Zone 2 - Drought Tolerant Species

Quan	Key	Botanical Name	Common Name	Seed
1989	G2-1	*Schizachyrium scoparium*	Little Blue Stem	✓

G-3/Zone 3 - Moist/Wet Soil Species

Quan	Key	Botanical Name	Common Name	Seed
1989	G3-1	*Sorghastrum nutans*	Indian Grass	✓

Landscape Treatment Type D

All bioswale areas to be sodded

SCHOLLEN & Company Inc.
220 Duncan Mill Road, Suite 109
Don Mills, Ontario M3B 3J5
Tel: (416) 441-3044
Fax: (416) 441-6010

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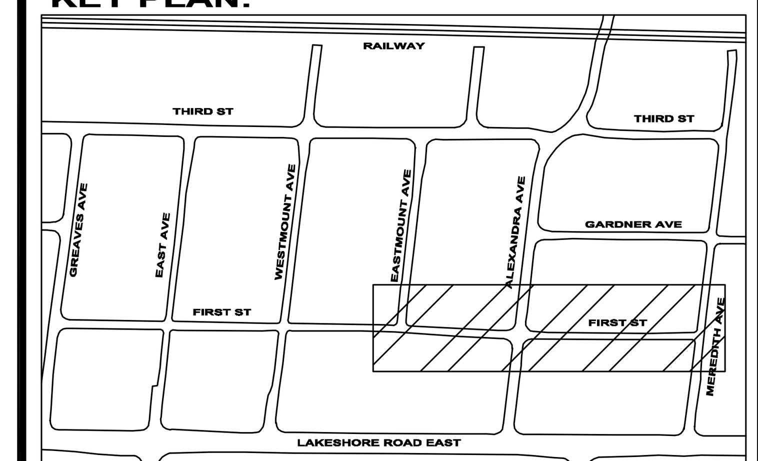

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ISSUED FOR TENDER	PT	06/09/2011

Aquafor Beech Limited
#6-202-2600 SKYMARK Ave,
MISSISSAUGA, ONTARIO, L4W 5B2
PHONE: (905) 629-0099, FAX: (905) 629-0089

MISSISSAUGA Leading today for tomorrow

FIRST & THIRD STREET RECONSTRUCTION

PROJECT No.: 10128

LANDSCAPE PLAN

FIRST STREET

FROM STA. 0+300 TO STA. 0+560

DESIGNED BY: RICHARD MARK SCHOLLEN — ONTARIO ASSOCIATION OF LANDSCAPE ARCHITECTS — OALA — MEMBER

APPROVED BY: LICENSED PROFESSIONAL ENGINEER — P. K. TEWARI — PROVINCE OF ONTARIO

DRAWN BY: CR/JH/SR

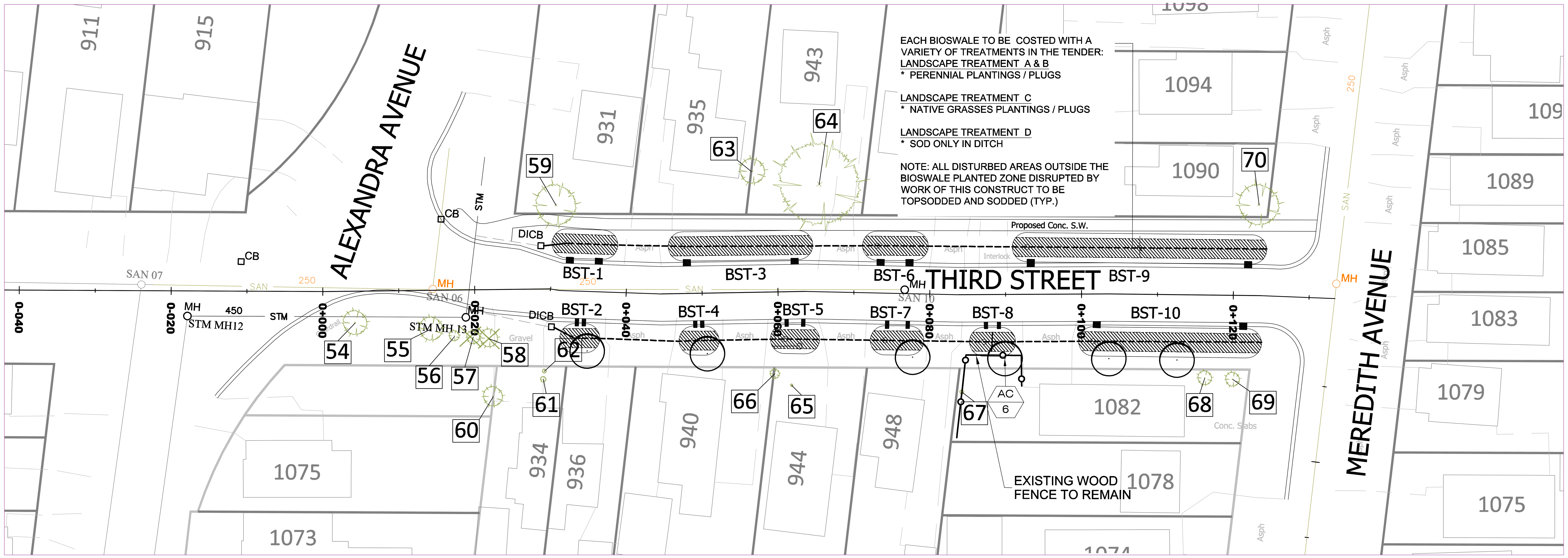
DATE: (MM.DD.YY) 12.20.11

SCALE: 1:300

SHEET No. 1

DWG. No. LP-1

C48725



THIRD STREET

construction NORTH

true NORTH

THE POSITION OF THE POLE LINES, CONDUITS, WATERMAINS, SEWERS, AND OTHER UTILITIES AND STRUCTURES ARE N O T NECESSARILY SHOWN ON THE CONTRACT DRAWINGS, AND WHERE SHOWN, THE ACCURACY OF THE POSITION OF SUCH UTILITIES AND STRUCTURES IS NOT GUARANTEED.

BEFORE STARTING WORK

THE CONTRACTOR SHALL CONFIRM THE POSITION AND EXACT LOCATION OF ALL SUCH UTILITIES, AND SHALL ASSUME ALL LIABILITY FOR ANY DAMAGE TO THEM MADE DURING THE COURSE OF THE CONTRACT WORK.

KEY PLAN:

LEGEND

CROSS - SECTION # / LOCATION SHEET #
PROPERTY/ BUILDING LINE
EXISTING TREE
BIO-SWALE UNIT
FLOW DIRECTION
SEDIMENT LOGS
CURB CUT
EXISTING FENCE/HEDGE
EXISTING TREE TO BE REMOVED
PERFORATED PIPE
SOLID PIPE
OVERFLOW RISER

GENERAL NOTES:

1. THIS SET OF DRAWINGS TO BE READ IN CONJUNCTION WITH ACCOMPANYING DESIGN BRIEF.
2. ALL ELEVATIONS ARE IN METRES AND REFERENCED TO LOCAL DATUM. ALL DIMENSIONS ARE IN METRIC UNITS.
3. THE CONTRACTOR SHALL BE RESPONSIBLE FOR LAYOUT AND SURVEY CONTROL DURING CONSTRUCTION.
4. THE CONTRACTOR IS RESPONSIBLE FOR LOCATION OF ALL EXISTING UTILITIES PRIOR TO CONSTRUCTION.
5. THE CONTRACTOR SHALL DELINEATE THE REQUIRED WORKING AREA ON-SITE PRIOR TO THE START OF WORK AND SHALL CONFINE OPERATIONS WITHIN THE DEFINED AREA. ALL ACTIVITIES, INCLUDING MAINTENANCE PROCEDURES, WILL BE CONTROLLED TO PREVENT ENTRY OF PETROLEUM PRODUCTS, DEBRIS, RUBBLE, CONCRETE OR OTHER DELETERIOUS SUBSTANCES INTO ANY WATER/WATERCOURSE/WETLAND NATURAL FEATURE, STORM SEWER OR SANITARY SEWER.
6. EROSION AND SEDIMENT CONTROL MEASURES (AND TREE/SHRUB PROTECTION BARRIERS) WILL BE IMPLEMENTED PRIOR TO AND MAINTAINED DURING THE CONSTRUCTION PHASES TO PREVENT ENTRY OF SEDIMENT INTO ANY FUTURE BIOSWALE OR PERMEABLE PAVEMENT FACILITY. THESE EROSION AND SEDIMENT CONTROL MEASURES WILL BE REMOVED FOLLOWING CONSTRUCTION COMPLETION AND WHEN DISTURBED AREAS HAVE BEEN STABILIZED AND VEGETATION ESTABLISHED.
7. ALL AREAS WHICH REMAIN DISTURBED FOR MORE THAN 30 DAYS MUST BE STABILIZED TO THE SATISFACTION OF THE RELEVANT AGENCIES, THE CLIENT AND OR THE SITE ENGINEER.
8. ALL SITE RESTORATION TO BE IN ACCORDANCE WITH THE LANDSCAPE REHABILITATION PLANS AND DETAILS.
9. THE CONTRACTOR IS TO PROVIDE CITY OF MISSISSAUGA WITH 7 DAYS ADVANCE NOTICE PRIOR TO INITIATION OF CONSTRUCTION.
10. THE CONTRACTOR IS RESPONSIBLE FOR REMOVAL AND DISPOSAL OF ALL DEBRIS.
11. ALL SEDIMENTS AND EROSION CONTROL MEASURES SHALL BE INSPECTED DAILY TO ENSURE THAT THEY ARE FUNCTIONING PROPERLY AND ARE MAINTAINED AND/OR UPGRADED AS REQUIRED

REVISION	By	MM/DD/YY
RE - ISSUED FOR TENDER	PT	12/20/2011
ISSUED FOR TENDER	PT	06/09/2011

TREE INVENTORY AND ASSESSMENT: BIO-SWALE AREA AND PLANT QUANTITY

Tree #	Species		Diameter (cm) Approx.	General Condition
	Species Common Name	Botanical Name		
54	Norway Maple	*Acer platanoides*	31	Healthy; Disturbing wire
55	Norway Maple	*Acer platanoides*	30	Healthy; Disturbing wire
56	Norway Maple	*Acer platanoides*	13	Healthy; Disturbing wire
57	Norway Maple	*Acer platanoides*	17	Healthy; Disturbing wire
58	Norway Maple	*Acer platanoides*	23	Healthy; Disturbing wire
59	White Spruce	*Picea glauca*	52	Healthy
60	Northern Catalpa	*Catalpa speciosa*	25	Healthy
61	Ornamental Cherry	*Prunus*	7	Healthy
62	Norway Maple	*Acer platanoides*	5	Fall colouring
63	White Spruce	*Picea glauca*	32	Healthy
64	Red Maple	*Acer rubrum*	104	Healthy
65	Japanese Maple	*Acer palmatum*	3	Healthy
66	Manitoba Maple	*Acer negundo*	12	Healthy; Disturbing wire
67	Staghorn Sumac	*Rhus typhina*	5	Healthy
68	Eastern Redcedar	*Juniperus virginiana*	18	Healthy; Disturbing wire
69	Eastern Redcedar	*Juniperus virginiana*	18	Healthy; Disturbing wire
70	Red Ash	*Fraxinus pennsylvanica*	52	Healthy; Disturbing wire

THIRD STREET LP-3 (Width 3.7 m, planting area width 2.5 m)

BIO-SWALE AREA						FOUR ALTERNATIVE LANDSCAPE TREATMENT TO BE PRICED IN TENDER					
Bio-swale ID	Length (m)	Total Area (m2)	Planting Area (m2)	Quantity of Plugs (pc)	Sod Area within BS (m2)	Type A-Native Perennials (pc)		Type B-Native Perennials (pc)		Type C-Native Grasses (pc)	
						Zone 2	Zone 3	Zone 2	Zone 3	Zone 2	Zone 3
BST-1	8.3	30.2	20.75	**207**	9.45	104	104	104	104	104	104
BST-2	5.2	17.1	13	**130**	4.1	65	65	65	65	65	65
BST-3	18.9	70.3	47.25	**472**	23.05	236	236	236	236	236	236
BST-4	5.3	17.1	13.25	**132**	3.85	66	66	66	66	66	66
BST-5	6.8	21.8	17	**170**	4.8	85	85	85	85	85	85
BST-6	8.6	30.2	21.5	**215**	8.7	108	108	108	108	108	108
BST-7	7	24	17.5	**175**	6.5	88	88	88	88	88	88
BST-8	6.1	20.2	15.25	**152**	4.95	76	76	76	76	76	76
BST-9	33.5	126.1	83.75	**837**	42.35	419	419	419	419	419	419
BST-10	24.2	89.2	60.5	**605**	28.7	303	303	303	303	303	303
Sub Total		446.2	309.75	**3095**	136.45	1548	1548	1548	1548	1548	1548

Landscape Treatment Type A-Native Perennials	Zone 2 (50% of planting area) 155 m2	1548 pcs	NOTES: One specie per zone per plant list @ 0.3 mo/c
	Zone 3 (50% of planting area) 155 m2	1548 pcs	One specie per zone per plant list @ 0.3 mo/c
Landscape Treatment Type B-Native Perennials	Zone 2 (50% of planting area) 155 m2	1548 pcs	One specie per zone per plant list @ 0.3 mo/c
	Zone 3 (50% of planting area) 155 m2	1548 pcs	One specie per zone per plant list @ 0.3 mo/c
Landscape Treatment Type C-Native Grasses	Zone 2 (50% of planting area) 155 m2	1548 pcs	One specie per zone per plant list @ 0.3 mo/c
	Zone 3 (50% of planting area) 155 m2	1548 pcs	One specie per zone per plant list @ 0.3 mo/c
Landscape Treatment Type D-Sodded Swale Only)	100% of planting area 310 m2		

NOTE: ONLY ONE OF THE 4 OPTIONS TREATMENTS A–D SHOWN ABOVE WILL APPLY TO EACH OF THE BIOSWALES, TYPICALLY 'A' OR 'B', BUT OPTION 'C' AND 'D' ARE ALSO HOMEOWNER OPTIONS TO BE CONFIRMED ON SITE

PLANT SCHEDULE

Proposed Street Tree Planting

Quan	Key	Botanical Name	Common Name	Size	Root	Comments
	AS	*Acer saccharum*	Sugar Maple	60mm	WB	spacing as ind.
	AF	*Acer freemanni*	Freeman Maple	60mm	WB	
6	AC	*Amelanchier canadensis*	Downy Serviceberry	50mm	WB	
	AL	*Amelanchier laevis*	Allegheny Serviceberry	50mm	WB	
	CA	*Carpinus caroliniana*	Blue Beech	60mm	WB	
	CE	*Cercis canadenis*	Eastern Redbud	50mm	WB	

Landscape Treatment Type A

Root: All plants to be plugs
Spacing: All plants to be spaced 0.3m on center
Seeding: All corresponding seed species to be spread in the applicable zone

Perennial Planting

P-2/Zone 2 - Drought Tolerant Species

Quan	Key	Botanical Name	Common Name	Seed
1548	P2-1	*Rudbeckia hirta*	Black Eyed Susan	✓

P-3/Zone 3 - Moist/Wet Soils Species

Quan	Key	Botanical Name	Common Name	Seed
1548	P3-1	*Penstemon digitalis*	Foxglove Beardtongue	✓

Landscape Treatment Type B

Perennial Planting

P-2/Zone 2 - Drought Tolerant Species

Quan	Key	Botanical Name	Common Name	Seed
1548	P2-1	*Liatris spicata*	Dense Blazing Star	✓

P-3/Zone 3 - Moist/Wet Soils Species

Quan	Key	Botanical Name	Common Name	Seed
1548	P3-1	*Helenium autumnale*	Sneezeweed	✓

Landscape Treatment Type C

Native Grass Planting

G-2/Zone 2 - Drought Tolerant Species

Quan	Key	Botanical Name	Common Name	Seed
1548	G2-1	*Schizachyrium scoparium*	Little Blue Stem	✓

G-3/Zone 3 - Moist/Wet Soil Species

Quan	Key	Botanical Name	Common Name	Seed
1548	G3-1	*Sorghastrum nutans*	Indian Grass	✓

Landscape Treatment Type D

All bioswale areas to be sodded

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MISSISSAUGA
Leading today for tomorrow

FIRST & THIRD STREET RECONSTRUCTION

PROJECT No.: 10128

LANDSCAPE PLAN
THIRD STREET
FROM STA. 0+000 TO STA. 0+130

SCHOLLEN & Company Inc.
220 Duncan Mill Road, Suite 109
Don Mills, Ontario M3B 3J5
Tel: (416) 441-3044
Fax: (416) 441-6010

DESIGNED BY: ONTARIO ASSOCIATION OF LANDSCAPE ARCHITECTS, RICHARD MARK SCHOLLEN, OALA MEMBER

APPROVED BY: LICENSED PROFESSIONAL ENGINEER, P. K. TEWARI, PROVINCE OF ONTARIO

DRAWN BY: CR/JH/SR

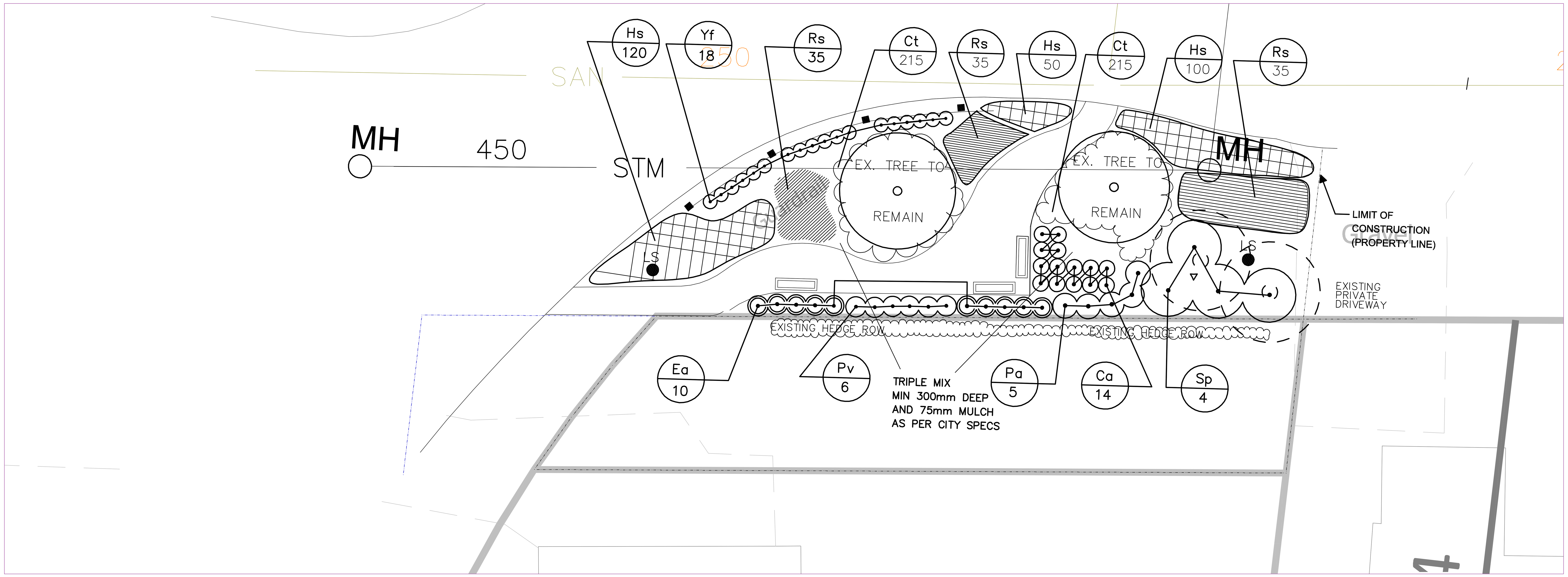
DATE: (MM.DD.YY) 12.20.11

SCALE: 1:300

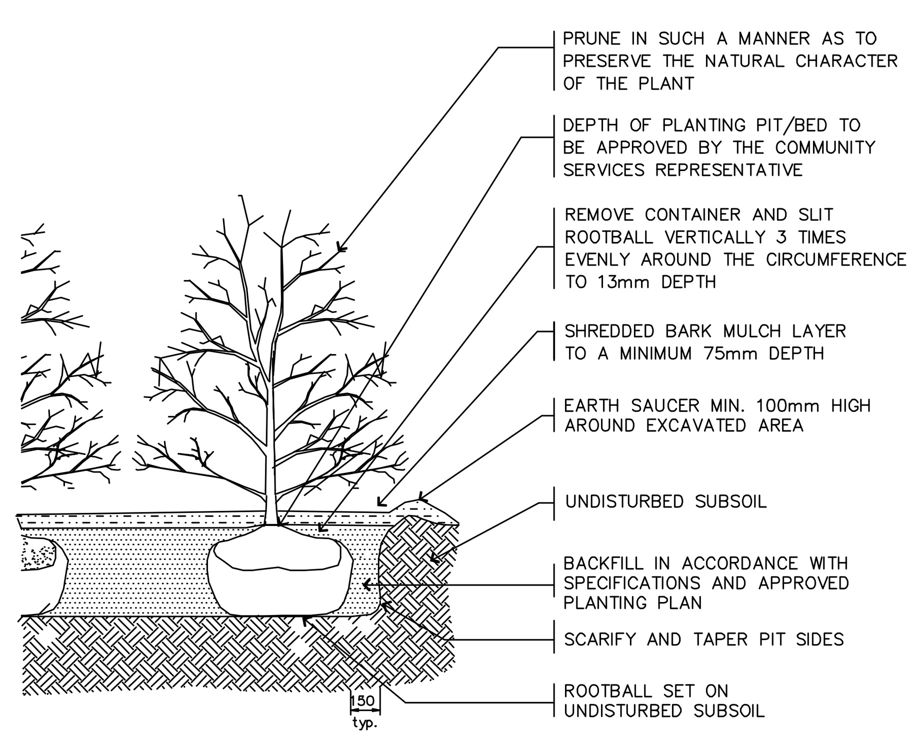
SHEET No. 2

C48726

DWG. No. LP-2



PLANTING PLAN



NOTES:

1. ALL PLANTING SHALL BE DONE UNDER THE DIRECTION AND SUPERVISION OF PERSONNEL WITH AT LEAST 5 YRS HORTICULTURAL AND PLANTING EXPERIENCE AND CONFORM TO BEST HORTICULTURAL PRACTICES
2. SAMPLES OF MULCH, TOP SOIL AND TREE ACCESSORIES MUST BE SUBMITTED TO COMMUNITY SERVICES FOR APPROVAL
3. PLANTING OF PLANT MATERIAL PRIOR TO COMMUNITY SERVICES APPROVAL WILL BE AT THE CONTRACTORS RISK. COMMUNITY SERVICES RESERVES THE RIGHT TO REJECT PLANT MATERIAL THAT DOES NOT CONFORM TO PLANTING PLAN SPECIFICATIONS
4. ONLY USE IMPORTED TOPSOIL WHEN TOPSOIL FROM SITE HAS BEEN DEPLETED OR IS UNACCEPTABLE TO COMMUNITY SERVICES
5. PLANTS SHALL BE SOUND HEALTHY, VIGOROUS AND WELL BRANCHED. THEY SHALL BE FREE OF INSECT PESTS' EGGS AND LARVAE AND SHALL HAVE HEALTHY WELL DEVELOPED ROOT SYSTEMS
6. KEEP ALL PLANTS WATERED FROM TIME OF PLANTING UNTIL ACCEPTANCE

NO.	REVISION	DATE

SCALE: N.T.S.
DATE: JANUARY 2001
DRAWN BY: P & D
NUMBER: 02950-4

TYPICAL CONTINUOUS SHRUB PLANTING BED

	Key	Scientific Name	Common Name	QTY	CONDITION
Grasses	Ca	Calamagrostis x acutifolia 'Karl Foerster'	Karl Forester Reed Grass	14	1 GALLON
	Pa	Pennisetum alopecuroides	Fountain Grass	5	1 GALLON
	Pv	Panicum virgatum 'Cloud Nine'	Cloud Nine Switch Grass	6	1 GALLON
Perennials	Ct	Cerastium tomentosum	Snow in Summer	430	1 GALLON
	Hs	Hemerocallis 'Stella de Oro'	Stella D'Oro Daylilly	270	1 GALLON
	Rs	Rudbeckia serotina	Black Eyed Susan	110	1 GALLON
Shrubs	Ea	Euonymus alatus 'Compactus' Ea	Dwarf Burning Bush	10	60cm
	Sp	Spirea prunifolia	Bridal Wreath Spirea	4	80cm
	Yf	Yucca Filamentosa	Adams Needle	18	3 GALLON

construction NORTH | true NORTH

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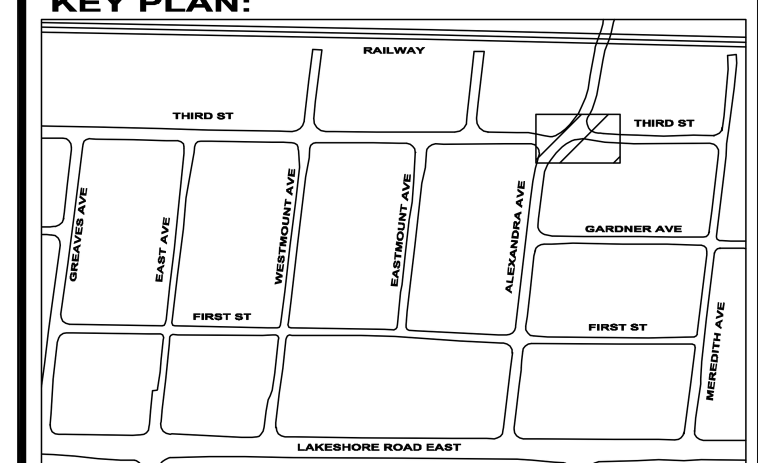

LEGEND

- CROSS - SECTION # / LOCATION SHEET #
- PROPERTY/ BUILDING LINE
- EXISTING TREE
- BIO-SWALE UNIT
- FLOW DIRECTION
- SEDIMENT LOGS
- CURB CUT
- PROPOSED GUARD RAIL
- EXISTING TREE TO REMAIN
- PROPOSED SHRUB OR GRASS
- EXISTING TREE FOR REMOVAL
- LIGHT STANDARD
- BENCH

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LAYOUT PLAN NOTES:

1. SUPPLY AND INSTALL Three (3), 6' METAL BENCHES, PORT CREDIT MODEL #1077 BY TORONTO FABRICATING AND MANUFACTURING. CO, C/W SKATEBOARD DEFLECTORSBLACK, TAMPER PROOF S.S OR GALVANIZED BOLTS CONTACT ZABEDA, PHONE: 905 891 2516
2. ALL PLAN DIMENSIONS ARE IN MILLIMETERS UNLESS OTHERWISE NOTED.

REVISION	By	MM/DD/YY
RE - ISSUED FOR TENDER	PT	12/20/2011
ISSUED FOR TENDER	PT	06/09/2011

Aquafor Beech Limited
#6-202-2600 SKYMARK Ave, MISSISSAUGA, ONTARIO, L4W 5B2
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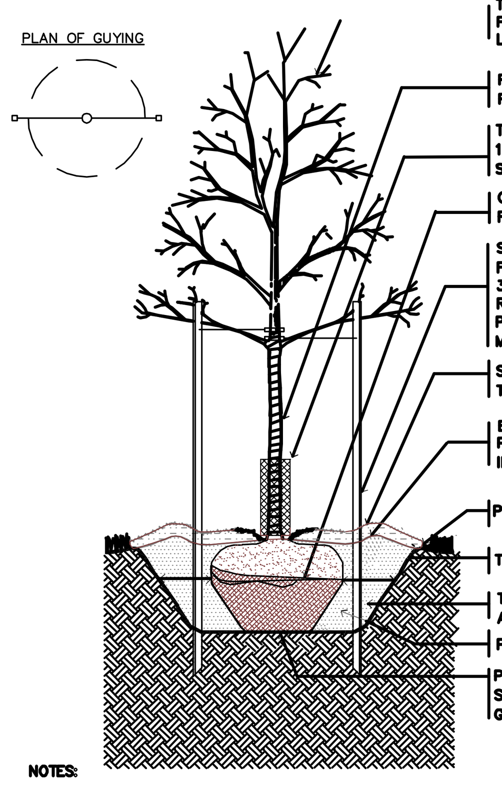
MISSISSAUGA Leading today for tomorrow

FIRST & THIRD STREET RECONSTRUCTION

PROJECT No.: 10128

LANDSCAPE PLAN PARKETTE _ THIRD STREET

DESIGNED BY:	APPROVED BY:	DRAWN BY: CR/JH
	P. K. TERRELL	DATE: (MM.DD.YY) 12.20.11
		SCALE: 1:100
		SHEET No. 3
C48727		DWG. No. LP-3



NOTES:

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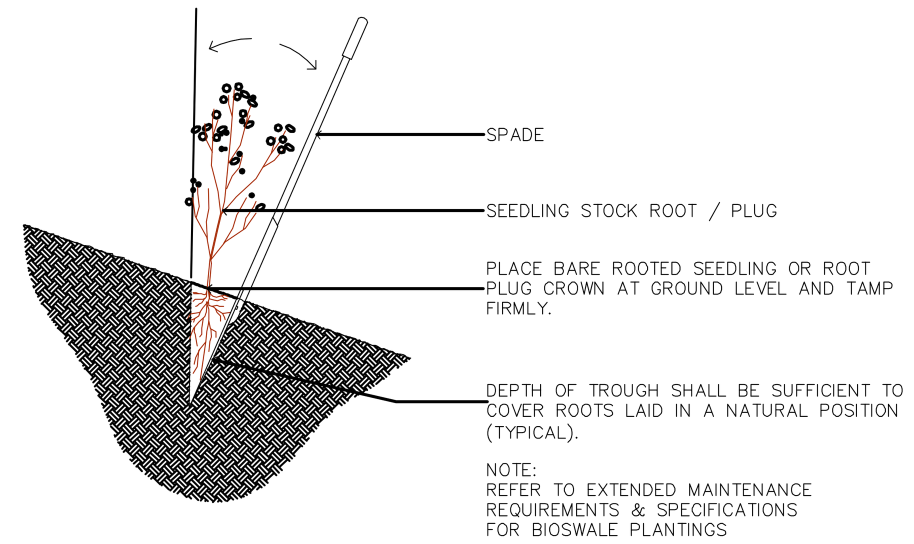
4. PLANTS SHALL BE SOUND HEALTHY, VIGOROUS AND WELL BRANCHED. THEY SHALL BE FREE OF INSECT PESTS' EGGS AND LARVAE AND SHALL HAVE HEALTHY WELL DEVELOPED ROOT SYSTEMS
5. KEEP ALL PLANTS WATERED FROM TIME OF PLANTING UNTIL ACCEPTANCE
6. NO TREE PIT SHALL BE LEFT OPEN OVERNIGHT.
7. REMOVE STAKES AND WIRES BY SECOND GROWING SEASON OR END OF WARRANTY PERIOD.
8. ALL DIMENSIONS ARE IN MILLIMETERS UNLESS OTHERWISE NOTED.

1 LD-1 DECIDUOUS TREE PLANTING
TYPICAL INSTALLATION FOR TREES 50mm CALIPER AND LARGER — N.T.S



2 LD-1 SEED SPECIFICATION — N.T.S

PLANTING MAINTENANCE NOTES

GENERAL SEEDING NOTE:
SOWING RATES FOR GRASS AND WILDFLOWER MIXES TO BE 4.5 TO 5.5 KG (10-12 LBS) PER ACRE WITH A NURSE CROP OF ANNUAL RYEGRASS AT 9 KG (20 LBS) PER ACRE. REFER TO SUPPLIER'S SPECIFICATIONS FOR MANUALLY APPLIED RATES. AREA TO BE SEEDED TO BE CLEARED OF WEEDS AND CULTIVATED.

Supplier: Pickseed Canada 1-800-661-4769 email@pickseed.com

Rate: Mixes are designed to be planted at 4.5 to 5.5kg (10-12 lbs) per acre or 250 grams (1/2 lb) per 1000 sq. ft.
Seed annual ryegrass as a nurse crop and for erosion control at 4.5kg (10 lbs) per acre.

3 LD-1 SEED SPECIFICATION — N.T.S

GENERAL:

1. All plant material shall be nursery stock conforming to the latest edition of the Canadian Standards for Nursery Stock as published by the Canadian Nursery Landscape Association.

2. All plants shall be healthy, vigourous plants, free from defects, decay, disfiguring roots, sun-scald injuries, bark abrasions, plant diseases and pests and all forms of infestations or objectionable disfigurements.

3. All plants shall be true to name, size, condition and quantity as per plan and plant list specifications.

4. All plant material shall be unwrapped prior to inspection. The City reserves the right to inspect all plant material and reject all material that does not meet the standards listed herein.

5. Substitutions will not be accepted without prior written request by the consulting Landscape Architect and written approval by the City. Additional plant quantities will be required to compensate for approved reduction in size due to unavailability of materials, to the satisfaction of the City.

TREES:

6. All trees shall be open-grown for wind-firmness. Trees shall not be leaning or have significant sweep, crook or bend. Deciduous trees shall have approximately two-thirds of their total height in living branches. All trees shall have good crown shape and colour (evergreens) characteristic of their species. Trees shall have a single dominant leader with no side branches taller / longer than the main leader.

7. If required, trees shall be properly target pruned (never flush cut, trimmed, rounded-over, hedged, tipped or topped) and dead / damaged branches shall be removed. Branches that cross-over each other or rub against each other, co-dominant leaders, and branches growing upward inside the crown shall be properly pruned. Trees shall not be treated at any time with wound paint.

8. All trees shall have root ball sizes that meet or exceed nursery standards. Root balls shall be firm and structurally integral with the trunk.

PLUG PLANTING AND GROUND COVERS:

9. Plugs and ground covers shall be true native species specified. Plugs / Root systems shall be ample, well-balanced and fibrous, capable of sustaining vigorous growth. Plants that are weak or thin, undersized, or have been cut back from larger grades to meet specifications shall be rejected.

GENERAL:

1. All landscaping shall be installed in accordance with the City Landscaping and Servicing Standards, and in accordance with the executed Site Plan Agreement.

2. The Owner agrees to retain the consulting Landscape Architect to administer and inspect landscape installations, and to certify the Landscape Works in conformance to the approved plans upon Completion and again upon Municipal Acceptance of the Works at the expiry of the Maintenance Guarantee period, in accordance with the executed Site Plan Agreement.

TOPSOIL REQUIREMENTS:

1. Topsoil shall be a fertile, natural loam, capable of sustaining healthy growth; containing a minimum of 4% organic matter for clay loams and 2% organic matter for sandy loam, to a maximum of 25% by volume. Topsoil shall be loose and friable, free of subsoil, clay lumps, stones, roots or any other deleterious material greater than 50mm diameter. Topsoil shall be free of all litter and toxic materials that may be harmful to plant growth. Topsoil containing sod clumps, crabgrass, couchgrass or other noxious weeds is not acceptable. Topsoil shall not be delivered or placed in a frozen or excessively wet condition. Topsoil acidity / alkalinity shall be in the range of 6.0pH to 7.5pH.

2. Where required, at the discretion of the City, the Contractor shall be required to provide topsoil test recommendations to the City confirming topsoil type (i.e. percentage of sand, silt, clay and organic content), macro and micronutrient content and pH levels. The Contractor shall ensure fertilizers and soil amendments are incorporated into the topsoil in accordance with topsoil test recommendations.

3. Topsoil depth requirements are as follows:
   - Boulevards **(Street Tree locations)**: 600mm minimum continuous depth.
   - Sodded / Seeded / Plug Planting Areas: 200mm minimum continuous depth.

4. All Sodded Areas to be prepared with a minimum of 75mm of nursery grade screened topsoil as per 1. above.

BED PREPARATION:

Tree pits and planting beds shall be backfilled to the specified depths approved native topsoil / planting soil mix.

SERVICES, STAKEOUTS & PLANTING ADJUSTMENTS

Contractors shall obtain stakeouts from all Utilities prior to landscape installations.
Tree location to be verified adjacent buried services, obtain PUCC clearance.

GENERAL PLANTING NOTES

MUNICIPAL MAINTENANCE GUARANTEE PERIOD:

The Municipal Maintenance Guarantee Period for all Landscape Works shall be a minimum of two (2) years including two (2) full growth seasons for all plant materials.

Maintenance activities shall commence upon Municipal Completion (Substantial Performance) of the Landscape Works, or portions thereof as certified by the consulting Landscape Architect and approved by the City, and shall continue until certification of Acceptance of Landscape Works in accordance with the executed Site Plan Agreement.

GENERAL MAINTENANCE ACTIVITIES:

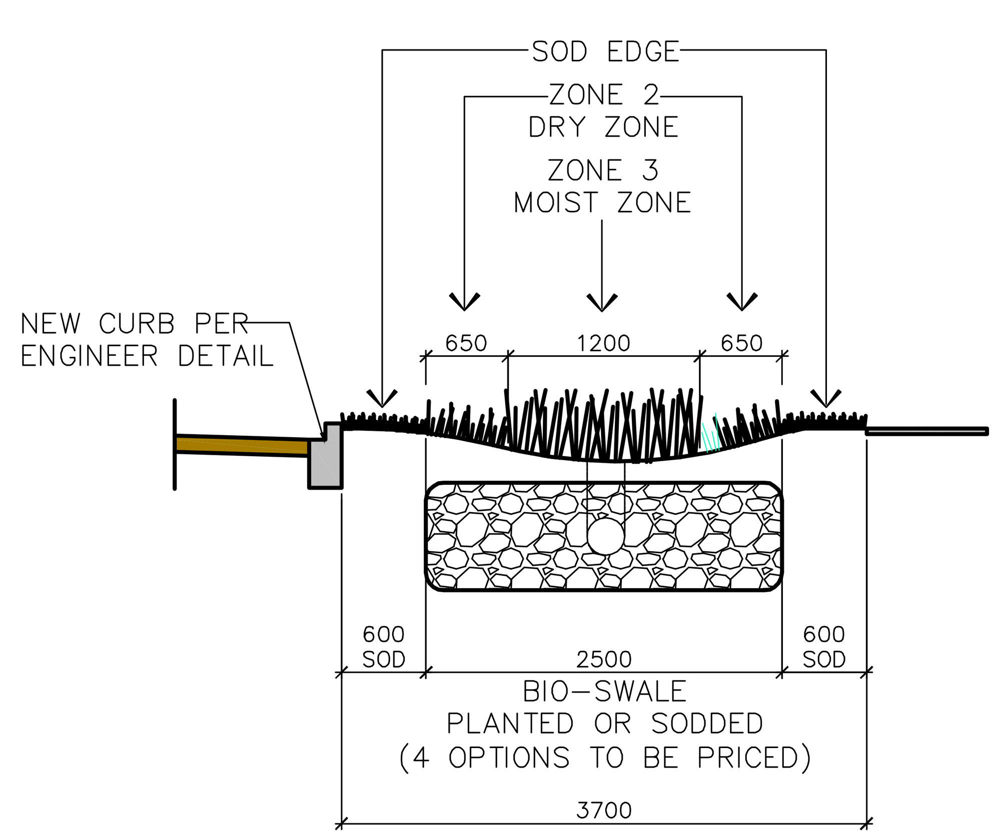
General maintenance requirements for trees, shrubs and groundcovers shall be performed a minimum of once per growing season and shall include, but not be limited to the following activities:

1. Watering (in addition to watering at time of planting / sodding / seeding) to ensure and maintain continuous healthy growth throughout the maintenance period.
2. Weed control: cultivation / hand removal of weeds in tree pits and shrub beds.
3. Disease and insect control: Method and application to approval of City Parks Division.
4. Topping / restoring mulch to ensure 75mm depth; clearing mulch from trunk flare.
5. Pruning of dead and damaged branches. Wound dressing as required.
6. Fertilizing (when required) based on topsoil test recommendations. Do not fertilize spring-planted trees at time of planting; fertilize in fall after leaf abscission.
7. Replacement of unacceptable or dead material.
8. Straightening of trees that lean, adjustments of supports and stakes.
9. Raising / adjusting trees that settle or are planted too low.
10. Any other procedure consistent with good horticultural practice necessary to ensure normal, healthy growth of planted material.

For maintenance inspection of hard landscape components (i.e. paving, signs etc.) Refer to general warranty specification Deficiencies observed shall be documented and remedied in a timely manner.

PLANTING SEQUENCING:

1. PLANTING IS NOT TO OCCUR PRIOR TO 5 DAYS AFTER MEDIA PLACEMENT TO ALLOW FOR MEDIA SETTLEMENT. ADD ADDITIONAL MEDIA IF REQUIRED.
2. PLANTING IS TO OCCUR IN ACCORDANCE WITH THE BIOSWALE PLANTING PLAN SHEET 13-16. AS NECESSARY, PROVIDE A MINIMUM OF 1 IRRIGATION PER WEEK IN THE FIRST 2 MONTHS.
3. AFTER PLANTING, BIOSWALE SHALL BE SEEDED AS PER LANDSCAPE DETAIL FOLLOWED BY 25mm SHREDDED HARDWOOD MULCH (AGED A MINIMUM OF 12 MONTHS) TO BE PLACED ON TOP OF THE BIOSWALE MEDIA AND AROUND PLANT MATERIAL.
4. PLANTING SHOULD BE INSPECTED BY THE CONTRACTOR AFTER EACH STORM > 10mm OR A MIN. OF TWICE POST INSTALLATION DURING THE FIRST 6 MONTHS AFTER PLANTING. DAMAGED PLANTINGS TO BE REPLACED WITH OUT ANY COST TO THE OWNER.
5. PLANTING TO BE INSPECTED A MIN. ONCE ANNUALLY (TYPICALLY IN SPRING) AND AFTER EACH EVENT GREATER THAN 60mm.



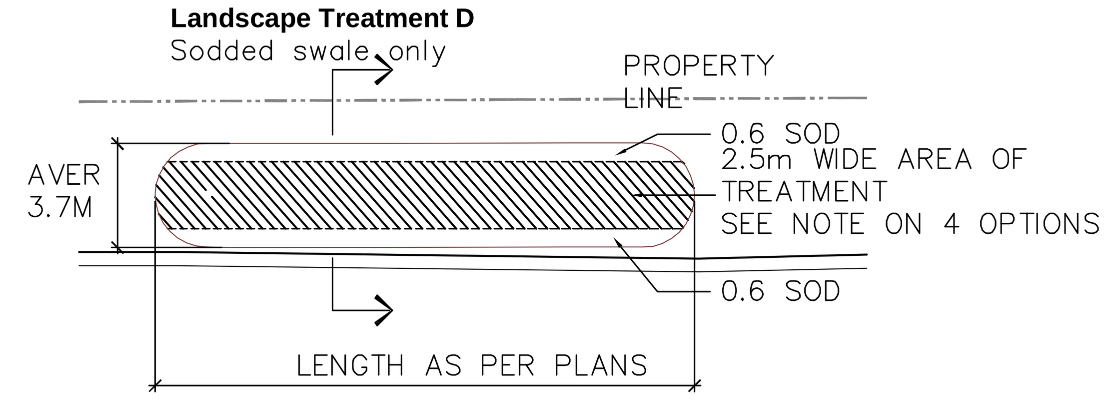
NOTE FOUR OPTION FOR TREATMENT:

Landscape Treatment A
Perennial plug planting in the two zones - 2 Species

Landscape Treatment B
Perennial plug planting in the two zones - 2 Species

Landscape Treatment C
Native grass plug planting in the two zone - 2 Species

Landscape Treatment D
Sodded swale only



4 LD-1 TYPICAL BIOSWALE SWALE PLANTING ZONE
PLAN AND SECTION — N.T.S

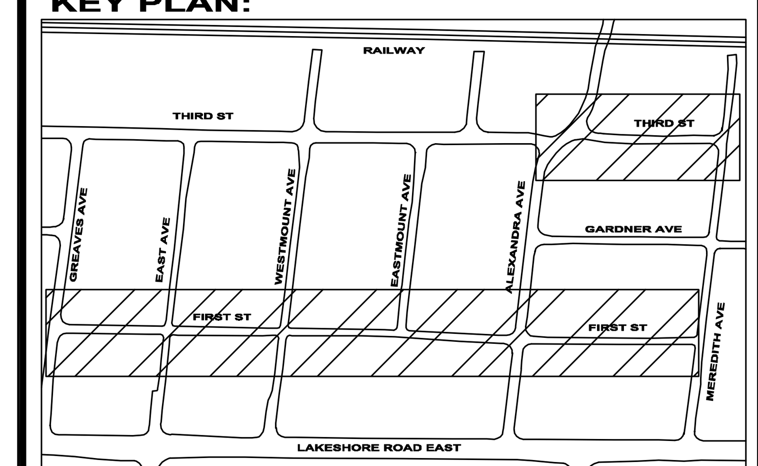
SCHOLLEN & Company Inc.
220 Duncan Mill Road, Suite 109
Don Mills, Ontario M3B 3J5
Tel: (416) 441-3044
Fax: (416) 441-6010

construction NORTH | true NORTH

THE POSITION OF THE POLE LINES, CONDUITS, WATERMAINS, SEWERS, AND OTHER UTILITIES AND STRUCTURES ARE N O T NECESSARILY SHOWN ON THE CONTRACT DRAWINGS, AND WHERE SHOWN, THE ACCURACY OF THE POSITION OF SUCH UTILITIES AND STRUCTURES IS NOT GUARANTEED.

BEFORE STARTING WORK
THE CONTRACTOR SHALL CONFIRM THE POSITION AND EXACT LOCATION OF ALL SUCH UTILITIES, AND SHALL ASSUME ALL LIABILITY FOR ANY DAMAGE TO THEM MADE DURING THE COURSE OF THE CONTRACT WORK.

KEY PLAN:



LEGEND

- CROSS - SECTION # / LOCATION SHEET #
- PROPERTY/ BUILDING LINE
- EXISTING TREE
- BIO-SWALE UNIT
- FLOW DIRECTION
- SEDIMENT LOGS
- CURB CUT
- EXISTING FENCE/HEDGE
- EXISTING TREE TO BE REMOVED
- PERFORATED PIPE
- SOLID PIPE
- OVERFLOW RISER

GENERAL NOTES:

1. THIS SET OF DRAWINGS TO BE READ IN CONJUNCTION WITH ACCOMPANYING DESIGN BRIEF.
2. ALL ELEVATIONS ARE IN METRES AND REFERENCED TO LOCAL DATUM. ALL DIMENSIONS ARE IN METRIC UNITS.
3. THE CONTRACTOR SHALL BE RESPONSIBLE FOR LAYOUT AND SURVEY CONTROL DURING CONSTRUCTION.
4. THE CONTRACTOR IS RESPONSIBLE FOR LOCATION OF ALL EXISTING UTILITIES PRIOR TO CONSTRUCTION.
5. THE CONTRACTOR SHALL DELINEATE THE REQUIRED WORKING AREA ON-SITE PRIOR TO THE START OF WORK AND SHALL CONFINE OPERATIONS WITHIN THE DEFINED AREA. ALL ACTIVITIES, INCLUDING MAINTENANCE PROCEDURES, WILL BE CONTROLLED TO PREVENT ENTRY OF PETROLEUM PRODUCTS, DEBRIS, RUBBLE, CONCRETE OR OTHER DELETERIOUS SUBSTANCES INTO ANY WATER/WATERCOURSE/WETLAND NATURAL FEATURE, STORM SEWER OR SANITARY SEWER.
6. EROSION AND SEDIMENT CONTROL MEASURES (AND TREE/SHRUB PROTECTION BARRIERS) WILL BE IMPLEMENTED PRIOR TO AND MAINTAINED DURING THE CONSTRUCTION PHASES TO PREVENT ENTRY OF SEDIMENT INTO ANY FUTURE BIOSWALE OR PERMEABLE PAVEMENT FACILITY. THESE EROSION AND SEDIMENT CONTROL MEASURES WILL BE REMOVED FOLLOWING CONSTRUCTION COMPLETION AND WHEN DISTURBED AREAS HAVE BEEN STABILIZED AND VEGETATION ESTABLISHED.
7. ALL AREAS WHICH REMAIN DISTURBED FOR MORE THAN 30 DAYS MUST BE STABILIZED TO THE SATISFACTION OF THE RELEVANT AGENCIES, THE CLIENT AND OR THE SITE ENGINEER.
8. ALL SITE RESTORATION TO BE IN ACCORDANCE WITH THE LANDSCAPE REHABILITATION PLANS AND DETAILS.
9. THE CONTRACTOR IS TO PROVIDE CITY OF MISSISSAUGA WITH 7 DAYS ADVANCE NOTICE PRIOR TO INITIATION OF CONSTRUCTION.
10. THE CONTRACTOR IS RESPONSIBLE FOR REMOVAL AND DISPOSAL OF ALL DEBRIS.
11. ALL SEDIMENTS AND EROSION CONTROL MEASURES SHALL BE INSPECTED DAILY TO ENSURE THAT THEY ARE FUNCTIONING PROPERLY AND ARE MAINTAINED AND/OR UPGRADED AS REQUIRED

RE - ISSUED FOR TENDER	PT	12/20/2011
ISSUED FOR TENDER	PT	06/09/2011
REVISION	By	MM/DD/YY

Aquafor Beech Limited
#6-202-2600 SKYMARK Ave,
MISSISSAUGA, ONTARIO, L4W 5B2
PHONE: (905) 629-0099, FAX: (905) 629-0089

MISSISSAUGA
Leading today for tomorrow

FIRST & THIRD STREET RECONSTRUCTION

PROJECT No.: 10128

LANDSCAPE DETAILS

FIRST & THIRD STREET

DESIGNED BY: ONTARIO ASSOCIATION OF LANDSCAPE ARCHITECTS — RICHARD MARK SCHOLLEN — OALA MEMBER

APPROVED BY: LICENSED PROFESSIONAL ENGINEER — P. K. TEWARI — PROVINCE OF ONTARIO

DRAWN BY: CR/JH/SR

DATE: (MM.DD.YY) 12.20.11

SCALE:

SHEET No. 4

C48728

DWG. No. LD-1

LAKEVIEW, CITY OF MISSISSAUGA

LOW IMPACT DEVELOPMENT INFRASTRUCTURE PERFORMANCE AND RISK MANAGEMENT ASSESSMENT

Appendix C
Data Management and Analytical Methodology

NOTICE

The contents of this report do not necessarily represent the policies of the supporting agencies. Although every reasonable effort has been made to ensure the integrity of the report, the supporting agencies do not make any warranty or representation, expressed or implied, with respect to the accuracy or completeness of the information contained herein. Mention of trade names or commercial products does not constitute endorsement or recommendation of those products.

DRAFT REPORT

1 DATA MANAGEMENT AND ANALYTICAL METHODOLOGY

CVC manages stormwater data produced from the ongoing monitoring of water level, flow and water quality at the Lakeview BMP study site. The processes for the collection of water level, flow, precipitation and water quality data is laid out in **Appendix A**. Provided here is a description on the data management and analysis activities for this site.

Statistical analyses for the Lakeview Retrofit site summarize available performance data and compare these data to other applicable BMP performance data sources. These analyses summarize the water quantity and quality effectiveness of the implemented BMPs, which can be used to guide CVC decision-making processes with respect to stormwater management and low impact development design.

1.1 Data Management

The collected site data include time series of precipitation and flow and composite water quality sample data. Data management includes initial processing and organizing, including identifying the site and reference input data to be analyzed and organization of the site data for event-based analysis.

1.1.1 Input Data Processing

The data analyses were completed with the Lakeview Retrofit monitoring data set provided by CVC. These data sets include data from three test sites; LV-2, LV-3, and LV-4. For LV-3, hydrologic data dates from August 2012. No water quality was collected from LV-3. For LV-4 and LV-2, hydrologic data dates from August 2012 and water quality data dates from September 2012.

Reference data included the following data sources:

- Northmount Avenue Conventional Curb and Gutter (herein referred to as the “water quality reference site” or “LV-1”) monitoring data provided by CVC. For LV-1, water quality data dates from July 2012.
- National Stormwater Quality Database (NSQD)
- International Stormwater BMP Database (BMPDB)
- Ontario Provincial Water Quality Objectives (PWQO) or Canadian Councils of Ministers of the Environment (CCME) Canadian Water Quality Guidelines for the Protection of Aquatic Life, whichever is more restrictive.

1.1.2 Input Data Organization

The flow and precipitation data were divided into hydrologic events associated with the collected water quality samples to provide meaningful, event-based analyses. Hydrologic events were defined using the time series of both flow and precipitation as defined in **Table 1-1**.

Table 1-1: Hydrologic Event Definition for CVC Data Analyses

Event Type	Beginning	End
Hydrologic Event	Flow *or* Precipitation > 2 mm	Flow *and* Precipitation = 0 for 6 consecutive hours

1.2 Data Analysis

Data analysis involved identifying appropriate evaluation and presentation (graphical) methods, and the data analysis tools and work flow as described in the following sections.

1.2.1 Data Analysis Evaluation Methods

The Lakeview Retrofit site was evaluated using event-based analysis, with the event defined as previously indicated in **Table 1-1**. LV-2 and LV-4 were evaluated for both water quantity and water quality performance. Because actual inflow data were not monitored for the sites, the Simple Method[1] was used to estimate influent volume as a product of a calculated runoff coefficient, the drainage area, and the event precipitation. Estimated influent volume was compared to actual effluent volume to evaluate BMP estimated volume reduction. It is recommended that this method for calculation of runoff could be improved through the development of a calibrated SWMM model[2]. Substantial existing flow and rainfall monitoring data could be used to calibrate and verify a hydrologic model for each site.

Simple Method

The standard method for evaluating stormwater BMPs is to compare untreated inflows to treated outflows. This method is used in comparing both water quality and quantity parameters such as volume reduction, peak flow or contaminate loading. Using water quality and quantity monitoring equipment can be useful for monitoring inflows however; it can be impractical due to possible disruption in the intended design of the practice in diverting runoff into the LID. Additionally, many BMPs have multiple inflow points into the practice making inflow monitoring expensive and complex and may still require some form of flow estimation.

The Simple Method is a spreadsheet based runoff estimation procedure that is used for determining stormwater runoff and pollutant loading for urban areas. The Simple Method determines estimated inflow based on drainage area, amount of precipitation, and a runoff coefficient. This information is used to determine a runoff coefficient[1]. While the Simple Method is typically used to calculate annual runoff, CVC has modified the formula to determine runoff on an event-by-event basis. CVC has also added a BMP component to account for LID areas. Note that the BMP area is not considered in the runoff coefficient calculation since complete infiltration into the practice is assumed for BMP areas.

The drainage area for Lakeview was derived using orthographic imagery, as-built surveys and site visits. This process allows the drainage area to be divided into impervious, pervious and BMP surfaces. Precipitation data is obtained from the rain gauge on the roof of the community Fire Station on Third Street at Cawthra Road. This data is used with the drainage area to determine event inflow runoff volume. **Tables 1-2** and **1-3** present the use of the Simple Method at LV-2 and LV-4.

The runoff coefficient is defined as:

$$Rv = 0.05 + 0.9 * la$$

Where:

Rv is the runoff coefficient

0.9 is the fraction of rainfall events that produce runoff

la is the impervious fraction (Impervious Area/Drainage Area to the BMP)

The modified Simple Method formula used is:

Event inflow volume (L): Drainage Area to the BMP (m^2) * Rv + BMP area (m^2) * Event Precipitation (mm)

Note: the BMP area is added since precipitation on the BMP area is considered to fully infiltrate into the practice.

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1 Schueler, T. 1987. Controlling Urban Runoff: A Practical Manual for Planning and Designing Urban BMPs. Metropolitan Washington Council of Governments. Washington, DC

2 EPA. (2010). "Storm Water Management Model (SWMM)." Water Supply and Water Resources Division, National Risk Management Research Laboratory, CDM.

Table 1-2: Drainage area and application of the Simple Method at LV-2

Land Use	**Area (m^2)**
Road	1,909
Roof (directed to impervious surfaces)	1,948
Driveway	1,981
Total impervious area	**5,838**
Grass	8,975
Roof (directed to pervious surfaces)	2,149
Total pervious area	**11,124**
Total drainage area to the BMP (impervious area + pervious area)	**16,962**
BMP Area	
Grass swale	541
Total BMP area	**541**
Ia= impervious fraction (total impervious area/total drainage area to the BMP)	0.344
Rv= 0.05 + 0.9 * Ia	0.360
Total drainage area to the BMP * Rv + total BMP area: Multiply this number by event precipitation (mm) to get event inflow volume (L)	**6647**

Table 1-3: Drainage area and application of the Simple Method at LV-4

Land Use	**Area (m^2)**
Road	438
Roof (directed to impervious surfaces)	292
Driveway	418
Total impervious area	**1,148**
Grass	2,070
Roof (directed to pervious surfaces)	567
Total pervious area	**2,637**
Total drainage area to the BMP (impervious area + pervious area)	**3,785**
BMP Area	
Bioswale	163
Permeable pavement	173
Total BMP area	**336**
Ia= impervious fraction (total impervious area/total drainage area to the BMP)	0.303
Rv= 0.05 + 0.9 * Ia	0.323
Total drainage area to the BMP * Rv + total BMP area: Multiply this number by event precipitation (mm) to get event inflow volume (L)	**1559**

Best results are produced when the method is used for smaller catchments at a development site scale. Further modeling would be required for determining runoff for a large watershed. Additionally, the Simple Method only provides estimates for the storm event itself and does not consider pollutant contribution from baseflow generated within the catchment.[3]

Lastly, the Simple Method can overestimate inflow volume for smaller events where rainfall depths would be used up by catchment wetting and surface depression storage. This occurs because the Simple Method applies the same runoff coefficient to storms of all magnitudes.

Simple Method for Extreme Event Runoff Estimation

To estimate a realistic inflow, Simple method runoff coefficient for this event was increased to reflect real-life hydrologic conditions during an intense rain event with very wet antecedent moisture conditions. Larger storms (greater than 50 mm) with high intensities and significant antecedent wetness can produce

3 Centre for Watershed Protection, (2010). Stormwater Management Design Manual. New York State Department of Environmental Conservation. Albany New York

a significant amount of runoff from pervious areas (Boyd et al., 1993). Therefore, the Simple method runoff coefficient value was increased to 0.75 for both the Lakeview sites to estimate influent volume for the July 8 storm. Runoff coefficient of 0.75 corresponds to an imperviousness of 80%. Actual imperviousness of LV-4 and LV-2 is 30 per cent and 35 per cent, respectively.

Water Quality

Both contaminant loadings and discharge concentrations have been evaluated for Lakeview. Loading reduction is the best way to evaluate water quality performance. However, to understand the filtration mechanism only discharge concentration was compared to reference water quality guidelines, runoff EMCs from similar land uses, and effluent concentrations for similar BMPs. The effluent EMC value from LV-1 was used as the influent EMC for LV-2 and 4. The effluent EMCs for LV-1 are derived from the lab reported value of the flow proportional samples collected on site for several parameters listed below. The statistical summaries have been organized by pollutant. Data set summary statistics are presented in both tabular and graphical formats.

The recommended parameters of interest analyzed are:

- Aluminum
- Cadmium
- Copper
- Iron
- Lead
- Nickel
- Zinc
- Dissolved Chloride
- Nitrate
- Total Kjeldahl Nitrogen
- Orthophosphate
- Total Phosphorus
- Total Suspended Solids

1.2.2 Data Analysis Presentation Methods

Tabular Summaries

The summary tables include both parametric and non-parametric statistics. Parametric statistics operate under the assumption that data arise from a single theoretical statistical distribution that can be described mathematically using coefficients, or parameters, of that distribution. The mean and standard deviation are example parameters of the normal, or Gaussian, distribution. Non-parametric statistics are fundamentally based on the ranks[4] of the data with no need to assume an underlying distribution. Non-parametric statistics do not depend on the magnitude of the data and are therefore resistant to the occurrence of a few extreme values (i.e., high or low values relative to other data points do not significantly alter the statistic).[5]

Graphical Summaries

Graphical summaries provided for the data sets include box plots and non-exceedance probability plots. Box plots (or box and whisker plots) provide a schematic representation of the central tendency and spread of the influent and effluent data sets. The box plots summarize the 25th and 75th percentiles, the median, outlying observations. The upper and lower 95th percent confidence intervals about the median are also presented, which can be used to indicate whether the influent median is statistically different than the effluent median (i.e., confidence intervals do not overlap). Figure 1-1 is a key for the box plots provided.

While box plots summarize the general spread of the data, probability plots illustrate the full empirical distribution of the data. A comparison of the reference site and effluent probability plots indicates whether there may be differences among all percentiles (not just the median) and whether the influent and effluent data sets are similarly distributed. Probability plots also provide a quick method of identifying the probability that an individual sample would be less than or equal to a particular value. For example, the effluent probability plot may be used to identify the probability that a particular water quality threshold or benchmark would be met (e.g., 40% chance that effluent concentration would be less than or equal to 1 mg/L).

Although the reference and effluent concentrations in a probability plot are not paired values, the relative position and slope of the two populations are a good indication of BMP effectiveness. A Regression-on-Order Statistics (ROS) method is used to estimate the values of non-detect results when the dataset as less than 80% non-detect results. Otherwise, the detection limits are shown on the probability plot.

4 In this context, ranks refer to the positions of the data after being sorted by magnitude.

5 Helsel, D.R. and R. M. Hirsch, 2002. Statistical Methods in Water Resources Techniques of Water Resources Investigations, Book 4, chapter A3. U.S. Geological Survey. 522 pages.

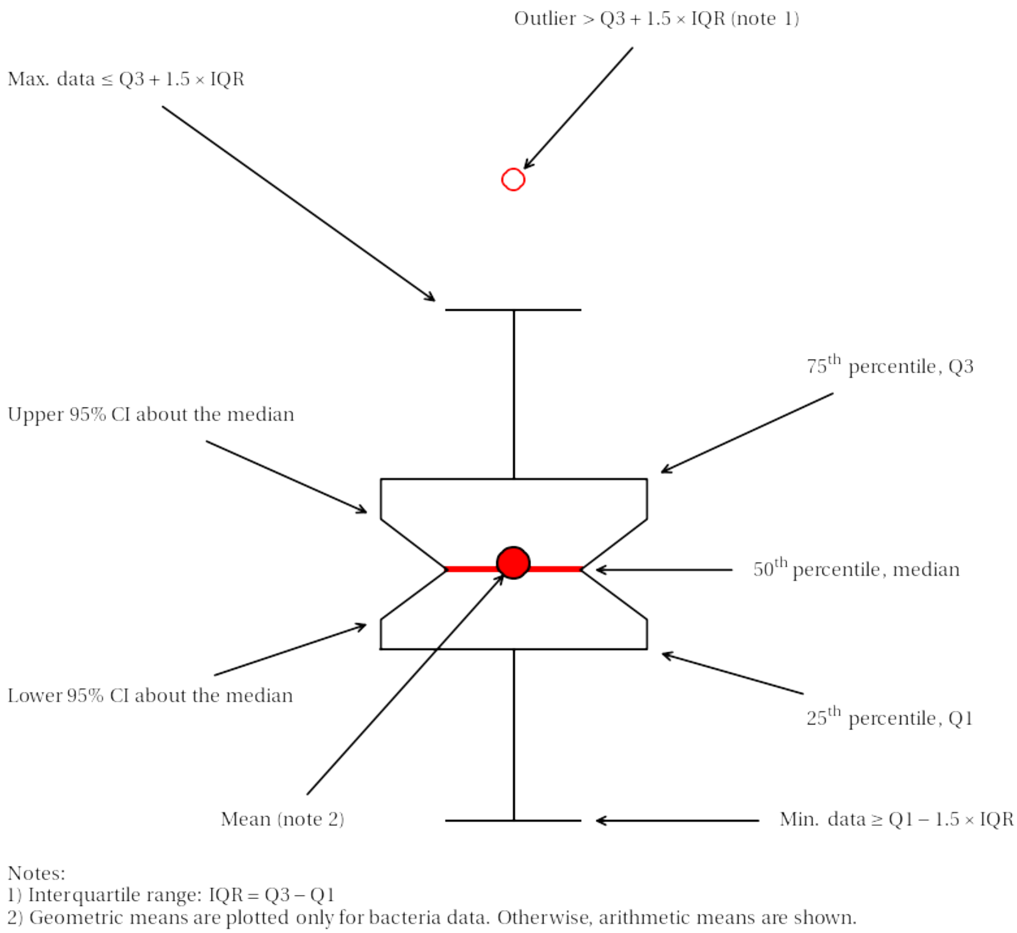


Figure 1-1: Explanation of Box and Whisker Diagram

1.2.3 Data Analysis Tools

Analysis algorithms and routines were implemented using the Python[6] programming language (v2.7.3). Python is an open source, dynamically typed, multi-paradigm language whose ease of use and simple, readable syntax is becoming increasingly favoured by scientists and engineers. With the prepared data, the analyses were conducted using several open source scientific and graphical extension libraries for Python. In addition to the standard library consistent across all Python 2.7.3 installations, openpyxl[7] was used to read the data from the Excel files via the pandas data analysis library[8]. Pandas, along with

6 http://www.python.org/

7 https://pypi.python.org/pypi/openpyxl/1.5.6

8 http://pandas.pydata.org/

NumPy[9] and SciPy[10] provided the basic tools needed to query, organize and compute statistics describing the data. All graphics were generated using matplotlib.[11]

This suite of data analysis tools is part of an emerging open-source standard known as PyLab.[12] The primary endeavor of the PyLab standard is to facilitate the creation of reproducible scientific analysis across all computing platforms (i.e., Windows, Mac OS X, and several distributions of Linux). The custom code created for this particular analysis adheres to this standard and accepted computing best practices (e.g., unit testing, code review). Furthermore, the results have been reproduced on up-to-date versions of Windows 7, Mac OS 10.7, and Linux Mint Maya.

1.2.4 Data Analysis Methodology

The analysis code serves four primary functions: 1) to read, organize, and query data in the spreadsheets; 2) to parse the hydrologic data into discrete storm events; 3) to use the timestamps of the water quality data to associate that data with the discrete storm events; and 4) to automatically generate summary tables, statistics and figures describing the storm events and their associated water quality data.

Each monitoring site spreadsheet is stored in an object containing the water quality and hydrologic data. The hydrologic data are indexed purely in time. The water quality has an index in time, as well as indices on the sample type (e.g., grab, composite), analytical parameter (e.g., copper, lead), and lab type (e.g., regular, lab duplicate). Only the data where the sample type is “composite” and where the lab type is “regular” are pertinent to the analysis. After all of the site specific data are read, indexed, and filtered to remove superfluous data such as the lab duplicates, the hydrologic data are resampled to a consistent 10-minute frequency and then parsed into discrete storm event begins as soon as the hydrologic record indicates either precipitation at or discharge from the site. The event ends after there has been no discharge and no precipitation at the site for 6 consecutive hours. With the discrete storm events, descriptive statistics such as the event duration, antecedent dry period, etc. are computed and stored as attributes of the storm. Finally, event hydrographs depicting the discharge, precipitation, and water quality sample times are constructed.

After the storm events have been defined, the code processes event data for each parameter of concern and computes basic summary statistics (e.g., mean, max, median) for all composite samples collected. Estimates of the mean and median are refined using a combination of Regression-on-Order-Statistics for handling non-detects[13] prior to computing summary statistics and the Bias Corrected and Accelerated (BCA) bootstrapping algorithm for computing confidence intervals[14]. Additionally, log-normal probability plots, box and whisker plots, and time series plots are constructed for each parameter using these refined statistics. The water quantity and quality results and statistics are then related back to the storm event during which they occurred, and various output tables are exported. In both cases of figures and tables, reference data can be included to provide context to the results.

Total influent volumes due to rainfall were estimated from a storm event’s total precipitation by using the Simple Method as discussed in **Section 1.2.1 Data Analysis Evaluation Methods.** Volume reductions were then computed as the difference between the estimated influent volume and measured effluent volume. Hydrologic lag times were then computed using the peak of precipitation hyetograph to the peak of effluent event hydrograph.

---

9 http://www.numpy.org/

10 http://www.scipy.org/

11 http://matplotlib.org/

12 http://www.scipy.org/PyLab

13 Helsel, D.R. and Cohn, T.A. (1988). “Estimation of Descriptive Statistics for Multiply Censored Water Quality Data.” Wat. Res. Research, 24(12): 1997-2004.

14 Efron, B. and Tibishirani (1993). An Introduction to the Bootstrap. Chapman & Hall, New York.

1.3 Table and Figure Definitions

Definitions for information found in the tables and figures presented in this report are included below for guidance.

Tables include a combination of the following results, listed in alphabetical order:

- *Antecedent Dry Period* - The amount of time with no rain preceding the event.
- *Effluent EMC* - The event mean concentration of the effluent for the event.
- *Estimated Pollutant Load Reduction* - The estimated mass of a pollutant passing through the BMP; what has been removed from the system.
- *Estimated Total Influent Load* - The estimated total pollutant load carried by influent for the event, as calculated by multiplying the Estimated Total Influent Volume by the NSQD Residential EMC.
- *Estimated Total Influent Volume* - The estimated total volume of influent for the event based on an application of the Simple Method with the measured rainfall depth.
- *Estimated Volume Reduction* - The estimated amount of volume removed as calculated by the difference between the Estimated Total Influent Volume and the Total Effluent Volume.
- *Event Duration* - The total length of time for the event.
- *Lag Time* - The time as calculated from the peak of precipitation event hyetograph to the peak of effluent event hydrograph.
- *Peak Effluent Flow* - The maximum effluent flow rate for the event based on measured effluent.
- *Peak Precipitation Intensity* - The maximum rate of precipitation for the event.
- *Sample Date* - The date the water quality sample was collected.
- *Storm Date* - The start date of the hydrologic event.
- *Total Effluent Load* - The total pollutant load carried by the effluent out of the BMP for the event, as calculated by multiplying the Total Effluent Volume by the Effluent EMC.
- *Total Effluent Volume* - The total measured volume effluent for the event.
- *Total Precipitation* - The total depth of rainfall for the event.
- *WQ Guideline* - The applicable PWQO or CCME water quality guideline for the pollutant.

Hydrologic Summary Figures presented in this report include the following results:

- *Flow* - The rate of flow for the estimated influent hydrograph and measured effluent hydrograph (in blue) with corresponding flow rates increasing upwards along the left chart axis.
- *10-min Precipitation Depth* - The depth of precipitation per 10-minute intervals with corresponding depths increasing downward along the right chart axis.

Tables and Comparative BMP Box Plots include the following BMPs represented in the BMPDB:

- *Bioretention* - Vegetated, shallow depressions used to temporarily store stormwater prior to infiltration, evapotranspiration, or discharge via an underdrain or surface outlet structure. Treatment is achieved through filtration, sedimentation, sorption, infiltration, biochemical processes and plant uptake.
- *Detention Basin* (a.k.a. Dry Pond) - Grass-lined basins that, while fully drainable between storm events, temporarily detain water through outlet controls to reduce peak stormwater runoff release rates and provide sedimentation treatment. Volume losses and load reductions through infiltration may also be significant.

- *Green Roof* - Vegetated roofs that provide stormwater treatment via filtration, sorption, biochemical processes and plant uptake.
- *Biofilter* - Vegetated swales or strips that provide treatment via filtration, sedimentation, infiltration, biochemical processes and plant uptake.
- *LID* - low-impact development (LID) monitored at a site-scale basis.
- Manufactured Device - Devices that are designed to provide various treatment processes such as sedimentation, skimming, filtration, sorption, and disinfection. Treatment process subcategories within the BMPDP include biological filtration, filtration, inlet insert, multi-process, physical (with volume control), physical (manufactured device), and oil/grit separators. The last two treatment process subcategories, which are of primary interest to CVC, are further described below:
    - Physical (manufactured device) are hydrodynamic devices that provide treatment via settling and includes proprietary devices like Stormceptors®. A performance summary[15] found statistically significant reductions for Zn and TP for physical (manufactured device) treatment processes. It was hypothesized that TSS results, showing no significant reductions, were affected by unusually low influent TSS concentrations.
    - Oil/grit separators are designed for removing floatables and coarse solids. The performance summary found statistically significant reductions for only TSS for oil/grit separators treatment processes.
- *Media Filter* - A constructed bed of filtration media that receives water at the surface and allows it to pond on the surface if inflows exceed the rate of percolation through the bed. Outflow from the media bed can be through underdrains or infiltration. Depending on the media used, treatment is provided via filtration, sorption, precipitation, ion exchange and biochemical processes.
- *Porous Pavement* - Pavement that allows for infiltration through surface void spaces into underlying material. Subcategories of porous pavement include modular block, pervious concrete, porous aggregate, porous asphalt, and porous turf. Treatment is provided via infiltration, filtration, sorption, and biodegradation.
- *Retention Pond* (a.k.a. Wet Pond) - Basins that feature a permanent pool of water (dead storage) below flood control (live storage) that is outlet controlled. Treatment is provided primarily through sedimentation; other treatment processes may include sorption and biochemical processes.
- *Wetland Basin* - Shallow basins typically designed with inflow energy dissipation and variable depths and vegetation types to promote interactions between runoff, aquatic vegetation, and wetland soils. Treatment is provided via sedimentation, sorption, biochemical processes, coagulation, flocculation, plant uptake and microbial transformations.
- *Wetland Channel* - Densely vegetated waterways used to treat and convey runoff. Treatment is provided via filtration, sedimentation, microbial transformations and plant uptake.

1.4 Statistical Significance and Hypothesis Testing Considerations

Statistical hypothesis testing is a powerful approach for evaluating stormwater BMP performance data. The most common type of statistical hypothesis testing involves comparisons of paired inflow and outflow EMC data to determine if the means significantly differ

At least 35 paired events are needed to verify that a statistically significant difference in concentration of 80% has been achieved. Long term assessment is needed to gain this confidence.

15 Leisenring, M., Clary, J., Hobson, P. 2012. International Stormwater Best Management Practices (BMP) Dat Summary. Prepared by Geosyntec Consultants, Inc. and Wright Water Engineers, Inc. July.

given an acceptable level of statistical confidence. This technique, which includes the paired t-Test, is commonly employed as a part of the analysis of the International Stormwater BMP Database and is a valuable statistical test for large, normally-distributed data sets. Nonparametric hypothesis testing, such as the Wilcoxon signed-rank test, can also be conducted (on medians rather than means); however, the statistical test generally is more powerful for parametric data when the normality assumptions hold (rare for stormwater). While statistical hypothesis testing is most commonly used for inflow/outflow analysis, it can be applied to any two data sets to determine if there is a statistically significant difference between the mean or median values of the two data distributions. In this case, tests on independent data sets are used (e.g., standard t-Test (parametric) and Mann-Whitney rank-sum test (non-parametric)) instead of matched pairs.

For the Lakeview site, the ability to conduct such testing is currently limited by the lack of measured inflow data. However, even if inflow EMCs had been measured or estimated from the initiation of monitoring, it is unlikely that the data set would be large enough for meaningful statistical hypothesis testing. To gain a sense of the size of the data set needed, consider hypothesis testing designed to detect a 75% difference between inflow and outflow mean EMC values for TSS (see Pitt and Parmer 1985[16]). Assuming a coefficient of variation of 1.5 (on the low end of variability for most stormwater parameters), a power of 80% (standard for this type of analysis) and a confidence level of 90%, more than 35 paired samples would need to be collected.

16 R. Pitt and K. Parmer. Quality Assurance Project Plan (QAPP) for EPA Sponsored Study on Control of Stormwater Toxicants. Department of Civil and Environmental Engineering, University of Alabama at Birmingham. 1995. Reprinted in Burton, G.A. Jr., and R. Pitt. Stormwater Effects Handbook: A Tool Box for Watershed Managers, Scientists, and Engineers. ISBN 0-87371-924-7. CRC Press, Inc., Boca Raton, FL. 2002. 911 pages.

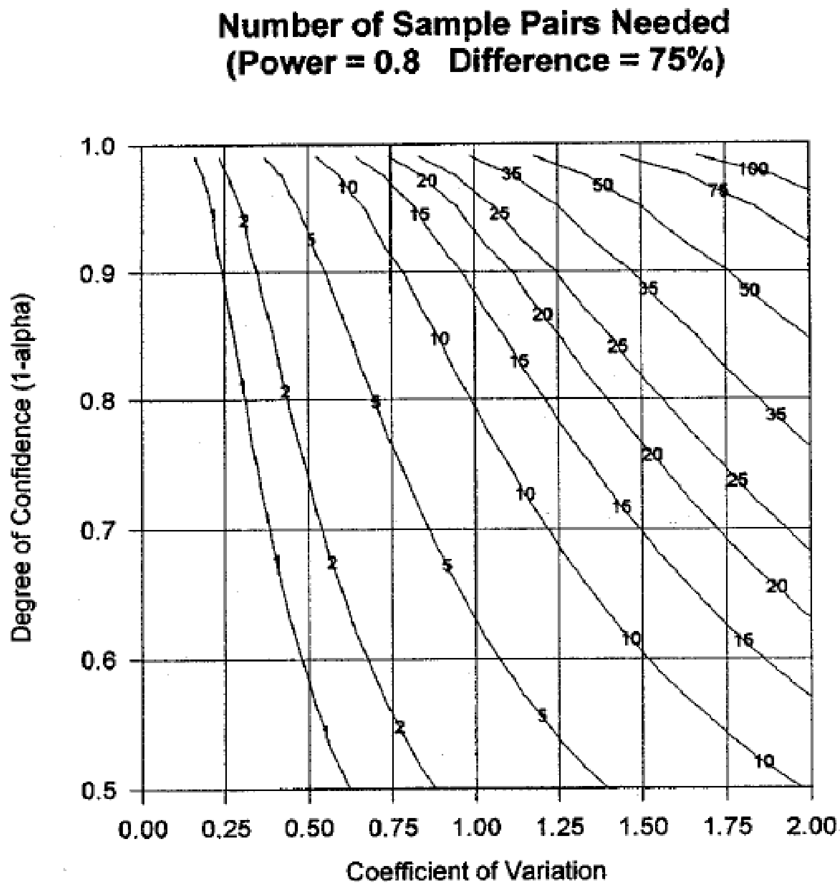


Figure 1-2: Statistical Hypothesis testing paired samples required to detect 75% difference in population means for power of 80% (Pitt and Parmer 1985)

Therefore, eventually it may be possible for CVC to conduct hypothesis testing if inflow EMCs can be estimate and/or measured and paired with outflow data; however, it will take at least several years to build a data set that is sizeable enough. Furthermore, if differences between inflow and outflow EMC distribution means are smaller (e.g. 20% reduction or even 50% reduction), greater numbers of paired samples will be needed to detect differences with confidence. While a large number of events are needed for statistical hypothesis testing, the site nonetheless is currently providing useful data that can be used to calculate annual outflow loads (with some associated uncertainty). CVC and Geosyntec/WWE are evaluating methods for estimating inflow loads (with associated uncertainty) based on land use defined from the 2013 survey of the watershed and EMC data from the NSQD. This will permit calculation of an annual load reduction for the facility. As the data set grows and if inflow EMC data can be collected from land uses within the watershed or entering the bioretention cells, the uncertainty of the comparison will decrease, permitting more accurate, and eventually statistically meaningful comparison.

If CVC is able to collect data for and/or estimate inflow EMCs, it should still be feasible to estimate inflow and outflow loads and calculate reductions on an annual basis to compare with the OMOE 80% TSS removal requirement, whether or not statistical significance holds (for small data sets, the conclusion often is that there is not a statistically significant difference; however, this finding may be reflective of the limited size of the data set rather than the lack of a true difference in population means/medians.

LAKEVIEW, CITY OF MISSISSAUGA

LOW IMPACT DEVELOPMENT INFRASTRUCTURE PERFORMANCE AND RISK MANAGEMENT ASSESSMENT

Appendix D

Data Analysis Summaries

DRAFT REPORT

1 RAINFALL EVENTS ANALYSIS

Table D-1: Summary of Rainfall Events for LV-2

Starting Date and Time	Event Duration (hrs)	Precipitation Depth (mm)
2012-01-01 0:00:00	26.0	3.4
2012-01-11 23:50:00	19.0	9.0
2012-01-16 21:50:00	22.7	5.4
2012-01-22 23:50:00	30.0	8.4
2012-01-26 17:30:00	22.0	9.8
2012-01-31 9:00:00	5.2	3.8*
2012-02-01 0:00:00	0.2	*
2012-02-11 4:20:00	11.5	2.4
2012-02-18 9:20:00	4.0	4.8
2012-02-24 9:30:00	9.5	9.5
2012-02-29 14:10:00	21.8	9.7
2012-03-02 21:10:00	11.0	5.3
2012-03-12 19:10:00	13.2	4.8
2012-03-18 9:20:00	1.7	4.6
2012-03-23 23:50:00	17.3	10.2
2012-09-08 0:10:00	14.5	38.4
2012-09-14 11:10:00	3.5	8.2
2012-09-18 4:10:00	10.5	17.2
2012-09-21 23:40:00	9.2	17.2
2012-10-05 21:40:00	5.7	8.8
2012-10-13 17:00:00	14.3	18.6
2012-10-17 7:30:00	3.5	2.6
2012-10-18 14:30:00	6.7	10.6
2012-10-19 22:00:00	5.0	4.0
2012-10-23 0:40:00	22.0	29.4
2012-10-27 5:40:00	10.2	21.2
2012-10-28 9:00:00	22.2	16.8
2012-10-29 13:30:00	12.3	12.2
2012-10-30 10:30:00	21.5	16.6
2012-10-31 14:30:00	17.5	4.8
2012-11-12 14:10:00	8.0	8.4
2012-12-02 3:20:00	9.2	11.6
2012-12-04 12:10:00	4.5	3.6
2012-12-08 8:10:00	3.0	3.0
2012-12-09 17:40:00	15.3	11.4
2012-12-16 8:10:00	6.7	4.4

Starting Date and Time	Event Duration (hrs)	Precipitation Depth (mm)
2012-12-20 17:00:00	13.3	10.8
2012-12-26 20:00:00	20.2	7.0
2012-12-29 4:50:00	9.7	4.8
2012-12-30 7:00:00	8.0	3.0
2013-01-11 4:00:00	13.8	6.4
2013-01-13 3:00:00	39.0	35.6
2013-01-25 13:30:00	6.3	3.6
2013-01-28 3:30:00	10.3	9.6
2013-01-28 23:50:00	88.5	22.2
2013-02-02 8:00:00	1.2	3.4
2013-02-07 18:30:00	15.7	3.6
2013-02-09 8:10:00	4.2	6.6
2013-02-11 2:10:00	333.5	21.8
2013-02-26 12:40:00	60.3	47.6
2013-03-03 7:20:00	1.8	3.0
2013-03-11 6:00:00	25.3	10.2
2013-03-18 17:50:00	20.0	4.8
2013-03-31 22:30:00	0.8	2.4
2013-04-08 15:20:00	9.3	10.8
2013-04-09 15:10:00	102.3	67.8
2013-04-17 22:30:00	8.0	3.4
2013-04-24 10:30:00	8.7	14.4
2013-04-28 17:30:00	13.3	12.2
2013-05-10 8:50:00	17.3	22.0
2013-05-15 4:10:00	2.2	3.2
2013-05-20 21:40:00	4.0	7.2
2013-05-22 14:30:00	2.3	2.2
2013-05-28 5:50:00	3.5	4.0
2013-05-28 16:20:00	25.7	27.4
2013-05-31 17:00:00	5.8	4.0
2013-06-02 0:50:00	14.0	7.4
2013-06-06 13:30:00	7.0	7.4
2013-06-10 7:50:00	22.0	33.0
2013-06-13 9:30:00	14.7	5.2
2013-06-16 5:10:00	6.7	10.8
2013-06-18 5:10:00	3.8	6.8
2013-06-22 12:40:00	1.2	4.2
2013-06-23 17:20:00	0.8	2.2
2013-06-25 6:20:00	0.8	4.6

Starting Date and Time	Event Duration (hrs)	Precipitation Depth (mm)
2013-06-28 4:00:00	13.2	6.6
2013-07-01 5:30:00	3.0	2.8
2013-07-03 12:00:00	0.3	4.0
2013-07-03 23:40:00	1.2	5.6
2013-07-05 6:30:00	16.2	15.2
2013-07-07 0:30:00	2.0	5.6
2013-07-07 16:40:00	10.2	19.4
2013-07-08 16:10:00	18.5	81.6
2013-07-19 17:10:00	9.0	12.6
2013-07-27 15:30:00	5.7	5.0
2013-07-31 15:30:00	19.3	27.6
2013-08-02 15:10:00	5.2	3.6
2013-08-26 3:40:00	9.3	15.4
2013-08-27 17:30:00	6.5	20.2
2013-09-07 7:50:00	6.7	19.8
2013-09-11 15:30:00	8.0	13.6
2013-09-20 22:00:00	18.7	34.0
2013-09-30 4:30:00	6.8	2.4
2013-10-04 0:30:00	3.3	9.8
2013-10-06 23:40:00	11.0	9.0
2013-10-13 6:20:00	10.5	10.8
2013-10-16 0:40:00	4.2	5.0
2013-10-17 16:20:00	2.8	7.4
2013-10-19 11:10:00	8.5	7.0
2013-10-21 18:00:00	6.7	7.2
2013-10-26 5:50:00	5.8	8.0
2013-10-31 3:20:00	7.0	13.6
2013-10-31 17:10:00	10.8	5.2
2013-11-02 9:10:00	6.8	2.0
2013-11-06 17:10:00	7.2	5.0
2013-11-17 2:40:00	3.0	4.6
2013-11-17 20:10:00	5.5	9.6
2013-11-21 6:00:00	3.0	2.6
2013-11-21 22:20:00	6.5	5.4
2013-11-26 20:10:00	9.3	4.8
2013-12-15 9:30:00	7.5	3.8
2013-12-19 23:40:00	59.0	43.6
2014-01-05 14:00:00	14.7	18.0
2014-01-10 0:50:00	8.2	5.8

Starting Date and Time	Event Duration (hrs)	Precipitation Depth (mm)
2014-01-11 0:30:00	16.0	9.4*
2014-01-12 15:20:00	0.2	*
2014-01-13 3:40:00	0.2	*
2014-01-13 13:30:00	17.2	*
2014-01-14 14:30:00	3.3	*
2014-01-26 5:00:00	8.8	7.0
2014-01-31 5:30:00	3.3	7.2
2014-02-01 10:50:00	14.2	14.8
2014-02-04 23:50:00	13.7	3.4
2014-02-06 9:50:00	2.0	2.2
2014-02-18 0:50:00	8.3	4.0
2014-02-20 15:50:00	54.5	19.8*
2014-02-23 14:50:00	4.3	*
2014-03-02 10:40:00	2.0	2.0
2014-03-10 6:00:00	3.0	2.8
2014-03-12 9:20:00	4.5	4.0
2014-03-19 15:50:00	10.5	4.8*
2014-03-21 12:20:00	6.8	*
2014-03-22 12:30:00	4.3	*
2014-03-27 21:40:00	29.3	3.2*
2014-03-29 14:20:00	3.0	*
2014-03-30 13:40:00	9.2	*
2014-03-31 13:20:00	40.8	*
2014-04-02 17:20:00	11.2	*
2014-04-04 10:10:00	12.0	9.2
2014-04-07 17:00:00	17.2	17.4
2014-04-12 23:20:00	4.8	7.4
2014-04-14 12:30:00	19.0	17.2
2014-04-25 15:20:00	4.7	5.2
2014-04-29 7:20:00	46.8	41.4
2014-05-13 3:30:00	5.0	14.6
2014-05-13 19:00:00	4.8	4.0
2014-05-14 17:00:00	8.3	10.2
2014-05-15 10:30:00	27.3	17.8
2014-05-20 8:10:00	12.0	3.0
2014-05-27 15:50:00	0.2	4.2
2014-06-02 23:30:00	11.7	5.8
2014-06-11 5:30:00	3.3	6.6
2014-06-11 21:10:00	8.2	14.4

Starting Date and Time	Event Duration (hrs)	Precipitation Depth (mm)
2014-06-17 17:50:00	1.8	10.8
2014-06-23 17:00:00	0.5	2.2
2014-06-24 12:00:00	8.0	3.4
2014-06-25 17:40:00	6.8	16.8
2014-06-29 19:00:00	0.5	3.8
2014-07-07 2:20:00	2.5	10.6
2014-07-07 14:20:00	1.2	5.2
2014-07-08 11:30:00	3.0	10.8
2014-07-13 5:10:00	6.3	10.8
2014-07-15 1:20:00	10.0	11.6
2014-07-19 13:50:00	8.0	6.0
2014-07-20 14:40:00	0.7	3.0
2014-07-27 18:50:00	14.8	33.6
2014-08-04 16:20:00	4.5	10.8
2014-08-11 22:50:00	7.7	23.4
2014-09-01 21:00:00	1.2	2.4
2014-09-02 11:30:00	4.5	11.2
2014-09-05 19:00:00	9.3	33.8
2014-09-10 15:50:00	13.5	17.8
2014-09-15 15:30:00	8.0	3.8
2014-09-20 21:40:00	13.8	15.6
2014-10-03 13:30:00	13.3	9.0
2014-10-06 22:20:00	10.0	3.6
2014-10-07 16:20:00	5.7	12.4
2014-10-14 22:40:00	6.3	2.4
2014-10-16 16:50:00	2.0	10.8
2014-10-20 13:40:00	6.5	2.0
2014-10-27 22:20:00	6.7	2.0
2014-10-31 4:40:00	22.3	13.4
2014-11-04 16:00:00	4.8	3.0
2014-11-06 17:20:00	8.0	2.6
2014-11-16 21:40:00	16.3	7.0
2014-11-22 17:40:00	3.7	2.2
2014-11-24 0:00:00	6.2	19.6
2014-12-11 3:30:00	21.8	11.0
2014-12-16 10:20:00	15.7	4.0
2014-12-24 20:20:00	2.8	6.0
2015-01-03 13:00:00	22.2	16.8
2015-01-29 13:10:00	7.5	7.0

Starting Date and Time	Event Duration (hrs)	Precipitation Depth (mm)
2015-02-03 10:30:00	2.0	4.2
2015-02-07 6:40:00	15.0	3.8
2015-02-21 9:10:00	8.8	6.4
2015-03-03 11:50:00	10.5	5.8*
2015-03-12 14:50:00	6.0	*
2015-03-13 15:20:00	4.3	*
2015-03-15 12:50:00	7.2	*
2015-03-21 1:40:00	2.5	2.0
2015-03-25 11:10:00	3.0	3.2
2015-04-02 18:20:00	0.8	3.2
2015-04-03 17:50:00	1.7	2.8
2015-04-08 10:20:00	4.5	14.8
2015-04-09 14:50:00	18.3	16.2
2015-04-13 16:40:00	1.5	4.4
2015-04-19 22:40:00	20.5	20.0
2015-04-21 11:50:00	16.2	7.2
2015-05-11 19:50:00	1.5	2.6
2015-05-30 12:50:00	32.8	47.8
2015-06-05 14:10:00	2.0	11.6
2015-06-07 20:10:00	15.2	20.2
2015-06-10 10:50:00	8.8	11.6
2015-06-12 3:50:00	14.3	10.0
2015-06-14 7:50:00	8.8	5.4
2015-06-16 2:40:00	9.2	12.2
2015-06-22 18:10:00	9.0	6.6
2015-06-27 10:40:00	53.5	54.0
2015-07-07 12:40:00	7.7	14.6
2015-07-14 19:30:00	0.7	3.0
2015-07-17 10:40:00	4.3	4.6
2015-07-17 23:30:00	9.5	11.0
2015-07-19 15:20:00	3.0	7.0

Note: * indicates that multiple precipitation events resulted in only one continuous flow event

Table D-1: Summary of Rainfall Events for LV-4

Starting Date and Time	Event Duration (hrs)	Precipitation Depth (mm)
2012-09-04 8:40:00	13.0	23.6
2012-09-06 6:10:00	2.8	2.2
2012-09-08 0:10:00	14.5	38.4
2012-09-14 11:10:00	3.5	8.2
2012-09-18 4:10:00	10.5	17.2
2012-09-21 23:40:00	9.2	17.2
2012-10-05 21:40:00	5.7	8.8
2012-10-13 17:00:00	14.3	18.6
2012-10-17 7:30:00	3.5	2.6
2012-10-18 14:30:00	6.7	10.6
2012-10-19 22:00:00	5.0	4.0
2012-10-23 0:40:00	22.0	29.4
2012-10-27 5:40:00	10.2	21.2
2012-10-28 9:00:00	22.2	16.8
2012-10-29 13:30:00	12.3	12.2
2012-10-30 10:30:00	21.5	16.6
2012-10-31 14:30:00	11.0	4.4
2012-11-12 14:10:00	7.7	8.4
2012-12-02 3:20:00	8.3	11.6
2012-12-04 12:10:00	4.5	3.6
2012-12-08 8:10:00	3.0	3.0
2012-12-09 17:40:00	13.8	11.4
2012-12-16 8:10:00	5.7	4.4
2012-12-20 17:00:00	13.3	10.8
2012-12-26 20:00:00	20.2	7.0
2012-12-29 4:50:00	9.7	4.8
2012-12-30 7:00:00	8.0	3.0
2013-01-11 4:00:00	13.8	6.4
2013-01-13 3:00:00	6.0	32.0
2013-01-13 20:40:00	10.0	3.6
2013-01-25 13:30:00	6.3	3.6
2013-01-28 3:30:00	10.3	9.6
2013-01-29 10:00:00	15.0	18.2
2013-01-30 8:50:00	18.0	3.8
2013-02-02 8:00:00	1.2	3.4
2013-02-07 18:30:00	15.7	3.6
2013-02-09 8:10:00	4.2	6.6
2013-02-11 2:10:00	13.7	5.4

Starting Date and Time	Event Duration (hrs)	Precipitation Depth (mm)
2013-02-14 17:20:00	4.2	2.2
2013-02-16 17:00:00	4.0	2.4
2013-02-19 5:00:00	4.0	9.8
2013-02-26 19:20:00	34.0	47.4*
2013-02-28 12:40:00	2.8	*
2013-03-03 7:20:00	1.8	3.0
2013-03-11 6:50:00	16.3	10.2
2013-03-18 17:50:00	7.0	4.4
2013-03-31 22:30:00	0.8	2.4
2013-04-08 15:20:00	6.2	10.8
2013-04-09 15:10:00	32.0	35.4
2013-04-11 6:00:00	40.2	29.2
2013-04-13 9:00:00	10.2	3.2
2013-04-17 22:30:00	6.3	3.4
2013-04-24 10:30:00	6.5	14.4
2013-04-28 17:30:00	11.3	12.2
2013-05-10 8:50:00	14.0	22.0
2013-05-15 4:10:00	2.2	3.2
2013-05-20 21:40:00	4.0	7.2
2013-05-22 14:30:00	2.3	2.2
2013-05-28 5:50:00	3.5	4.0
2013-05-28 16:20:00	20.7	27.4
2013-05-31 17:00:00	5.8	4.0
2013-06-02 0:50:00	2.2	3.8
2013-06-02 11:10:00	2.0	3.6
2013-06-06 13:30:00	7.0	7.4
2013-06-10 7:50:00	19.7	33.0
2013-06-13 9:30:00	14.7	5.2
2013-06-18 5:10:00	3.8	6.8
2013-06-22 12:40:00	1.2	4.2
2013-06-23 17:20:00	0.3	2.2
2013-06-28 4:00:00	13.2	6.6
2013-07-01 5:30:00	3.0	2.8
2013-07-03 12:00:00	0.3	4.0
2013-07-03 23:40:00	1.0	5.6
2013-07-05 6:30:00	11.0	15.2
2013-07-07 0:30:00	2.0	5.6
2013-07-07 16:40:00	10.2	19.4
2013-07-08 16:10:00	18.7	81.6*

Starting Date and Time	Event Duration (hrs)	Precipitation Depth (mm)
2013-07-09 20:00:00	2.7	*
2013-07-19 17:10:00	9.0	12.6
2013-07-27 15:30:00	5.7	5.0
2013-07-31 15:30:00	19.3	27.6
2013-08-02 15:10:00	5.2	3.6
2013-08-26 3:40:00	9.2	15.4
2013-08-27 17:30:00	6.5	20.2
2013-09-07 7:50:00	6.7	19.8
2013-09-11 15:30:00	8.0	13.6
2013-09-20 22:00:00	18.5	34.0
2013-09-30 4:30:00	6.8	2.4
2013-10-04 0:30:00	3.3	9.8
2013-10-06 23:40:00	11.0	9.0
2013-10-13 6:20:00	10.5	10.8
2013-10-16 0:40:00	4.2	5.0
2013-10-17 16:20:00	2.7	7.4
2013-10-19 11:10:00	8.5	7.0
2013-10-21 18:00:00	6.7	7.2
2013-10-26 5:50:00	5.8	8.0
2013-10-31 3:20:00	7.0	13.6
2013-10-31 17:10:00	10.8	5.2
2013-11-02 9:10:00	6.8	2.0
2013-11-06 17:10:00	7.2	5.0
2013-11-17 2:40:00	3.0	4.6
2013-11-17 20:10:00	5.5	9.6
2013-11-21 6:00:00	3.0	2.6
2013-11-21 22:20:00	6.5	5.4
2013-11-26 20:10:00	9.3	4.8
2013-12-15 9:30:00	7.5	3.8
2013-12-19 23:40:00	63.5	43.6
2014-01-05 14:00:00	14.7	18.0
2014-01-10 0:50:00	8.2	5.8
2014-01-11 0:30:00	15.3	9.4
2014-01-26 5:00:00	8.8	7.0
2014-02-01 10:50:00	14.2	14.8
2014-02-04 23:50:00	13.7	3.4
2014-02-06 9:50:00	2.0	2.2
2014-02-18 0:50:00	8.3	4.0
2014-02-20 15:50:00	18.2	19.0

Starting Date and Time	Event Duration (hrs)	Precipitation Depth (mm)
2014-03-02 10:40:00	2.0	2.0
2014-03-10 6:00:00	3.0	2.8
2014-03-12 9:20:00	4.5	4.0
2014-03-19 15:50:00	10.5	4.8
2014-03-27 21:40:00	11.8	3.2
2014-04-04 10:10:00	10.3	9.2
2014-04-07 17:00:00	12.0	17.4
2014-04-12 23:20:00	4.7	7.4
2014-04-14 12:30:00	2.2	7.4
2014-04-14 23:50:00	5.2	9.8
2014-04-25 15:20:00	3.8	5.2
2014-04-29 7:20:00	44.7	41.4
2014-05-13 3:30:00	1.5	14.6
2014-05-13 19:00:00	2.7	4.0
2014-05-14 17:00:00	1.7	10.2
2014-05-15 10:30:00	17.0	17.6
2014-05-20 8:10:00	12.0	3.0
2014-05-27 15:50:00	0.2	4.2
2014-06-02 23:30:00	11.7	5.8
2014-06-05 15:50:00	3.8	5.6
2014-06-11 5:30:00	3.3	6.6
2014-06-11 21:10:00	8.2	14.4
2014-06-17 17:50:00	0.7	10.8
2014-06-23 17:00:00	0.5	2.2
2014-06-24 12:00:00	8.0	3.4
2014-06-25 17:40:00	6.8	16.8
2014-06-29 19:00:00	0.5	3.8
2014-07-07 2:20:00	2.5	10.6
2014-07-07 14:20:00	0.3	5.2
2014-07-08 11:30:00	2.8	10.8
2014-07-13 5:10:00	6.3	10.8
2014-07-15 1:20:00	10.0	11.6
2014-07-19 13:50:00	8.0	6.0
2014-07-20 14:40:00	0.7	3.0
2014-07-27 18:50:00	16.0	33.6
2014-08-04 16:20:00	2.0	10.8
2014-08-11 22:50:00	7.7	23.4
2014-09-01 21:00:00	1.2	2.4
2014-09-02 11:30:00	3.8	11.2

Starting Date and Time	Event Duration (hrs)	Precipitation Depth (mm)
2014-09-05 19:00:00	17.5	34.0
2014-09-10 15:50:00	11.8	17.8
2014-09-15 15:30:00	8.0	3.8
2014-09-20 21:40:00	11.3	15.6
2014-10-03 13:30:00	13.3	9.0
2014-10-06 22:20:00	10.0	3.6
2014-10-07 16:20:00	5.7	12.4
2014-10-14 22:40:00	6.3	2.4
2014-10-16 16:50:00	1.5	10.8
2014-10-20 13:40:00	6.5	2.0
2014-10-27 22:20:00	6.7	2.0
2014-10-31 4:40:00	22.3	13.4
2014-11-04 16:00:00	4.8	3.0
2014-11-06 17:20:00	8.0	2.6
2014-11-16 21:40:00	16.3	7.0
2014-11-22 17:40:00	3.7	2.2
2014-11-24 0:00:00	6.2	19.6
2014-12-11 3:30:00	21.8	11.0
2014-12-16 10:20:00	15.7	4.0
2014-12-24 20:20:00	2.8	6.0
2015-01-03 13:00:00	22.2	16.8
2015-01-29 13:10:00	7.5	7.0
2015-02-03 10:30:00	2.0	4.2
2015-02-07 6:40:00	15.0	3.8
2015-02-21 9:10:00	8.8	6.4
2015-03-03 11:50:00	10.5	5.8
2015-03-21 1:40:00	2.5	2.0
2015-03-25 11:10:00	3.0	3.2
2015-04-02 18:20:00	0.8	3.2
2015-04-03 17:50:00	1.7	2.8
2015-04-08 10:20:00	4.0	14.8
2015-04-09 14:50:00	18.0	16.2
2015-04-13 16:40:00	1.5	4.4
2015-04-19 22:40:00	19.2	20.0
2015-04-21 11:50:00	7.3	7.0
2015-05-11 19:50:00	1.5	2.6
2015-05-30 12:50:00	32.8	47.8
2015-06-05 14:10:00	1.3	11.6
2015-06-07 20:10:00	15.2	20.2

Starting Date and Time	Event Duration (hrs)	Precipitation Depth (mm)
2015-06-10 10:50:00	6.7	11.6
2015-06-12 3:50:00	14.3	10.0
2015-06-14 7:50:00	8.8	5.4
2015-06-16 2:40:00	3.0	12.0
2015-06-22 18:10:00	9.0	6.6
2015-06-27 10:40:00	31.2	54.0
2015-07-07 12:40:00	7.7	14.6
2015-07-14 19:30:00	0.7	3.0
2015-07-17 10:40:00	4.3	4.6
2015-07-17 23:30:00	9.5	11.0
2015-07-19 15:20:00	0.3	7.0

Note: * indicates that multiple precipitation events resulted in only one continuous flow event

2 HYDROLOGIC ANALYSIS

Table D-2: Hydrologic Summary of Rainfall Events for LV-2

Starting Date and Time	Antecedent Dry Period (Days)	Total Inflow Volume (L)	Peak Inflow (L/s)	Total Outflow Volume (L)	Peak Outflow (L/s)	Peak Reduction (%)	Estimated Volume Reduction		
							(L)	Normalized (L/m^2)	(%)
2012-01-01 0:00:00		22587	8.9	22764	1.8225	79.4	-177	-0.010	-0.8
2012-01-11 23:50:00	9.9	59790	6.6	23038	2.289	65.5	36752	2.100	61.5
2012-01-16 21:50:00	0.9	35874	6.6	15370	1.044	84.3	20504	1.171	57.2
2012-01-22 23:50:00	1.0	55804	13.3	16404	5.248	60.5	39400	2.251	70.6
2012-01-26 17:30:00	0.3	65104	6.6	43278	2.4985	62.4	21826	1.247	33.5
2012-01-31 9:00:00	0.4	25245	11.1	25	0.0105	99.9	25219	1.441	99.9
2012-02-01 0:00:00	0.4	0		6	0.0105		-6	0.000	
2012-02-11 4:20:00	10.2	15944	2.2	0		100.0	15944	0.911	100.0
2012-02-18 9:20:00	1.2	31888	10.0	1844	0.684	93.1	30044	1.716	94.2
2012-02-24 9:30:00	2.2	63111	14.4	17873	2.785	80.7	45238	2.585	71.7
2012-02-29 14:10:00	4.8	64440	15.5	18632	2.018	87.0	45808	2.617	71.1
2012-03-02 21:10:00	1.4	35209	19.9	28283	4.412	77.9	6927	0.396	19.7
2012-03-12 19:10:00	3.1	31888	16.6	5818	1.387	91.6	26070	1.489	81.8
2012-03-18 9:20:00	0.4	30559	6.6	0		100.0	30559	1.746	100.0
2012-03-23 23:50:00	2.0	67762	6.6	0		100.0	67762	3.871	100.0
2012-09-08 0:10:00	167.3	255103	73.1	17269	12.973	82.2	237834	13.588	93.2
2012-09-14 11:10:00	5.9	54475	13.3	0		100.0	54475	3.112	100.0
2012-09-18 4:10:00	1.6	114265	26.6	0		100.0	114265	6.528	100.0
2012-09-21 23:40:00	0.9	114265	17.7	25433	3.77	78.7	88832	5.075	77.7
2012-10-05 21:40:00	13.5	58461	11.1	0		100.0	58461	3.340	100.0

Starting Date and Time	Antecedent Dry Period (Days)	Total Inflow Volume (L)	Peak Inflow (L/s)	Total Outflow Volume (L)	Peak Outflow (L/s)	Peak Reduction (%)	Estimated Volume Reduction		
							(L)	Normalized (L/m^2)	(%)
2012-10-13 17:00:00	1.7	123565	15.5	0		100.0	123565	7.060	100.0
2012-10-17 7:30:00	1.7	17273	6.6	0		100.0	17273	0.987	100.0
2012-10-18 14:30:00	1.1	70419	19.9	0		100.0	70419	4.023	100.0
2012-10-19 22:00:00	1.0	26573	6.6	0		100.0	26573	1.518	100.0
2012-10-23 0:40:00	2.5	195313	24.4	0		100.0	195313	11.159	100.0
2012-10-27 5:40:00	0.4	140838	11.1	0		100.0	140838	8.047	100.0
2012-10-28 9:00:00	0.7	111607	11.1	0		100.0	111607	6.376	100.0
2012-10-29 13:30:00	0.3	81048	13.3	14729	2.712	79.6	66319	3.789	81.8
2012-10-30 10:30:00	0.4	110279	68.6	51409	17.734	74.2	58870	3.363	53.4
2012-10-31 14:30:00	0.3	31888	4.4	894	0.163	96.3	30994	1.771	97.2
2012-11-12 14:10:00	1.6	55804	6.6	235	0.106	98.4	55569	3.175	99.6
2012-12-02 3:20:00	1.3	77062	11.1	6687	1.631	85.3	70375	4.021	91.3
2012-12-04 12:10:00	2.0	23916	6.6	954	0.457	93.1	22962	1.312	96.0
2012-12-08 8:10:00	0.5	19930	6.6	0		100.0	19930	1.139	100.0
2012-12-09 17:40:00	1.3	75734	11.1	10679	1.631	85.3	65054	3.717	85.9
2012-12-16 8:10:00	6.0	29231	13.3	613	0.227	98.3	28617	1.635	97.9
2012-12-20 17:00:00	4.1	71748	8.9	16678	2.712	69.4	55069	3.146	76.8
2012-12-26 20:00:00	1.8	46503	6.6	0		100.0	46503	2.657	100.0
2012-12-29 4:50:00	0.5	31888	4.4	0		100.0	31888	1.822	100.0
2012-12-30 7:00:00	0.7	19930	6.6	0		100.0	19930	1.139	100.0
2013-01-11 4:00:00	0.9	42517	6.6	4903	1.508	77.3	37615	2.149	88.5
2013-01-13 3:00:00	1.4	236501	26.6	173595	14.918	43.9	62906	3.594	26.6
2013-01-25 13:30:00	5.4	23916	4.4	0		100.0	23916	1.366	100.0
2013-01-28 3:30:00	1.8	63776	6.6	0		100.0	63776	3.644	100.0
2013-01-28 23:50:00	0.4	147481	13.3	158368	6.114	54.0	-10886	-0.622	-7.4
2013-02-02 8:00:00	0.7	22587	13.3	0		100.0	22587	1.290	100.0
2013-02-07 18:30:00	4.5	23916	4.4	0		100.0	23916	1.366	100.0
2013-02-09 8:10:00	0.9	43846	6.6	0		100.0	43846	2.505	100.0
2013-02-11 2:10:00	0.7	144824	8.9	417069	4.909	44.6	-272245	-15.554	-188.0
2013-02-26 12:40:00	1.5	316221	17.7	308410	9.802	44.7	7811	0.446	2.5
2013-03-03 7:20:00	2.3	19930	6.6	0		100.0	19930	1.139	100.0
2013-03-11 6:00:00	2.5	67762	6.6	8384	1.269	80.9	59377	3.392	87.6
2013-03-18 17:50:00	4.9	31888	6.6	3330	0.227	96.6	28558	1.632	89.6
2013-03-31 22:30:00	10.2	15944	19.9	0		100.0	15944	0.911	100.0
2013-04-08 15:20:00	7.7	71748	19.9	11875	5.764	71.1	59873	3.421	83.4
2013-04-09 15:10:00	0.6	450416	35.4	238296	9.421	73.4	212120	12.119	47.1
2013-04-17 22:30:00	1.3	22587	6.6	1968	0.544	91.8	20619	1.178	91.3
2013-04-24 10:30:00	4.3	95664	11.1	30235	3.459	68.8	65429	3.738	68.4
2013-04-28 17:30:00	2.1	81048	8.9	22597	2.569	71.0	58451	3.339	72.1

Starting Date and Time	Antecedent Dry Period (Days)	Total Inflow Volume (L)	Peak Inflow (L/s)	Total Outflow Volume (L)	Peak Outflow (L/s)	Peak Reduction (%)	Estimated Volume Reduction		
							(L)	Normalized (L/m^2)	(%)
2013-05-10 8:50:00	0.7	146153	35.4	62479	6.468	81.7	83673	4.781	57.3
2013-05-15 4:10:00	0.7	21259	26.6	0		100.0	21259	1.215	100.0
2013-05-20 21:40:00	5.6	47832	24.4	4862	3.155	87.0	42969	2.455	89.8
2013-05-22 14:30:00	1.5	14615	22.1	0		100.0	14615	0.835	100.0
2013-05-28 5:50:00	3.6	26573	4.4	0		100.0	26573	1.518	100.0
2013-05-28 16:20:00	0.3	182026	55.4	111458	17.734	68.0	70569	4.032	38.8
2013-05-31 17:00:00	1.1	26573	13.3	5996	1.887	85.8	20577	1.176	77.4
2013-06-02 0:50:00	0.4	49160	15.5	8184	3.459	77.7	40976	2.341	83.4
2013-06-06 13:30:00	3.9	49160	6.6	209	0.106	98.4	48951	2.797	99.6
2013-06-10 7:50:00	1.8	219229	48.7	93081	25.898	46.8	126148	7.207	57.5
2013-06-13 9:30:00	2.2	34545	13.3	3022	2.569	80.7	31524	1.801	91.3
2013-06-16 5:10:00	2.2	71748	17.7	21955	8.854	50.0	49792	2.845	69.4
2013-06-18 5:10:00	1.3	45174	19.9	0		100.0	45174	2.581	100.0
2013-06-22 12:40:00	4.2	27902	17.7	0		100.0	27902	1.594	100.0
2013-06-23 17:20:00	0.9	14615	24.4	4094	3.155	87.0	10521	0.601	72.0
2013-06-25 6:20:00	0.8	30559	35.4	2332	2.569	92.7	28227	1.613	92.4
2013-06-28 4:00:00	1.7	43846	13.3	13	0.021	99.8	43833	2.504	100.0
2013-07-01 5:30:00	2.5	18601	6.6	0		100.0	18601	1.063	100.0
2013-07-03 12:00:00	2.1	26573	28.8	0		100.0	26573	1.518	100.0
2013-07-03 23:40:00	0.5	37202	22.1	1153	1.758	92.1	36050	2.060	96.9
2013-07-05 6:30:00	0.6	100978	35.4	113665	22.967	35.2	-12687	-0.725	-12.6
2013-07-07 0:30:00	1.1	37202	17.7	965	0.375	97.9	36238	2.070	97.4
2013-07-07 16:40:00	0.6	128880	146.2	64885	50.475	65.5	63995	3.656	49.7
2013-07-08 16:10:00	0.6	542093	396.4	924949	381.068	3.9	-382856	-21.874	-70.6
2013-07-19 17:10:00	10.3	83706	53.1	4730	4.25	92.0	78975	4.512	94.3
2013-07-27 15:30:00	7.6	33217	28.8	0		100.0	33217	1.898	100.0
2013-07-31 15:30:00	3.8	183355	19.9	21307	5.418	72.8	162048	9.258	88.4
2013-08-02 15:10:00	1.2	23916	8.9	0		100.0	23916	1.366	100.0
2013-08-26 3:40:00	0.3	102307	73.1	3346	4.25	94.2	98961	5.654	96.7
2013-08-27 17:30:00	0.4	134195	35.4	21989	7.006	80.2	112206	6.411	83.6
2013-09-07 7:50:00	4.7	131537	26.6	3494	1.508	94.3	128043	7.315	97.3
2013-09-11 15:30:00	4.0	90349	39.9	5428	1.155	97.1	84921	4.852	94.0
2013-09-20 22:00:00	4.3	225872	26.6	2785	2.289	91.4	223088	12.746	98.8
2013-09-30 4:30:00	0.3	15944	6.6	0		100.0	15944	0.911	100.0
2013-10-04 0:30:00	3.5	65104	24.4	3049	4.25	82.6	62055	3.545	95.3
2013-10-06 23:40:00	0.6	59790	13.3	386	0.375	97.2	59403	3.394	99.4
2013-10-13 6:20:00	3.6	71748	24.4	4089	1.758	92.8	67659	3.866	94.3
2013-10-16 0:40:00	2.3	33217	17.7	0		100.0	33217	1.898	100.0
2013-10-17 16:20:00	1.1	49160	13.3	1054	0.544	95.9	48107	2.748	97.9

Starting Date and Time	Antecedent Dry Period (Days)	Total Inflow Volume (L)	Peak Inflow (L/s)	Total Outflow Volume (L)	Peak Outflow (L/s)	Peak Reduction (%)	Estimated Volume Reduction		
							(L)	Normalized (L/m^2)	(%)
2013-10-19 11:10:00	1.7	46503	6.6	0		100.0	46503	2.657	100.0
2013-10-21 18:00:00	1.9	47832	6.6	0		100.0	47832	2.733	100.0
2013-10-26 5:50:00	0.5	53146	4.4	0		100.0	53146	3.036	100.0
2013-10-31 3:20:00	1.2	90349	17.7	1127	0.832	95.3	89221	5.097	98.8
2013-10-31 17:10:00	0.3	34545	11.1	0		100.0	34545	1.974	100.0
2013-11-02 9:10:00	1.2	13287	4.4	0		100.0	13287	0.759	100.0
2013-11-06 17:10:00	4.0	33217	6.6	0		100.0	33217	1.898	100.0
2013-11-17 2:40:00	5.9	30559	13.3	0		100.0	30559	1.746	100.0
2013-11-17 20:10:00	0.6	63776	28.8	13662	6.646	76.9	50114	2.863	78.6
2013-11-21 6:00:00	3.2	17273	13.3	0		100.0	17273	0.987	100.0
2013-11-21 22:20:00	0.6	35874	4.4	0		100.0	35874	2.050	100.0
2013-11-26 20:10:00	4.2	31888	4.4	0		100.0	31888	1.822	100.0
2013-12-15 9:30:00	0.6	25245	4.4	0		100.0	25245	1.442	100.0
2013-12-19 23:40:00	1.1	289648	17.7	7192	1.887	89.3	282456	16.138	97.5
2014-01-05 14:00:00	0.4	119579	8.9	0		100.0	119579	6.832	100.0
2014-01-10 0:50:00	0.7	38531	8.9	0		100.0	38531	2.201	100.0
2014-01-11 0:30:00	0.6	62447	6.6	127	0.106	98.4	62320	3.561	99.8
2014-01-12 15:20:00	1.0	0		13	0.021		-13	-0.001	
2014-01-13 3:40:00	0.5	0		98	0.163		-98	-0.006	
2014-01-13 13:30:00	0.4	0		9368	0.375		-9368	-0.535	
2014-01-14 14:30:00	0.3	0		268	0.058		-268	-0.015	
2014-01-26 5:00:00	0.9	46503	8.9	0		100.0	46503	2.657	100.0
2014-01-31 5:30:00	4.1	47832	8.9	0		100.0	47832	2.733	100.0
2014-02-01 10:50:00	1.1	98321	8.9	0		100.0	98321	5.617	100.0
2014-02-04 23:50:00	3.0	22587	4.4	0		100.0	22587	1.290	100.0
2014-02-06 9:50:00	0.3	14615	6.6	0		100.0	14615	0.835	100.0
2014-02-18 0:50:00	8.5	26573	6.6	0		100.0	26573	1.518	100.0
2014-02-20 15:50:00	2.3	131537	19.9	121948	3.77	81.1	9590	0.548	7.3
2014-02-23 14:50:00	0.7	0		884	0.106		-884	-0.051	
2014-03-02 10:40:00	0.4	13287	4.4	0		100.0	13287	0.759	100.0
2014-03-10 6:00:00	5.6	18601	4.4	0		100.0	18601	1.063	100.0
2014-03-12 9:20:00	2.0	26573	4.4	0		100.0	26573	1.518	100.0
2014-03-19 15:50:00	6.0	31888	8.9	4466	0.832	90.6	27422	1.567	86.0
2014-03-21 12:20:00	1.4	0		5666	0.457		-5666	-0.324	
2014-03-22 12:30:00	0.3	0		483	0.058		-483	-0.028	
2014-03-27 21:40:00	5.2	21259	4.4	53355	0.936	78.9	-32096	-1.834	-151.0
2014-03-29 14:20:00	0.5	0		136	0.058		-136	-0.008	
2014-03-30 13:40:00	0.8	0		1160	0.106		-1160	-0.066	
2014-03-31 13:20:00	0.6	0		2755	0.058		-2755	-0.157	

Starting Date and Time	Antecedent Dry Period (Days)	Total Inflow Volume (L)	Peak Inflow (L/s)	Total Outflow Volume (L)	Peak Outflow (L/s)	Peak Reduction (%)	Estimated Volume Reduction		
							(L)	Normalized (L/m^2)	(%)
2014-04-02 17:20:00	0.5	0		886	0.058		-886	-0.051	
2014-04-04 10:10:00	1.2	61118	11.1	6889	1.631	85.3	54229	3.098	88.7
2014-04-07 17:00:00	2.8	115593	11.1	36673	3.614	67.4	78921	4.509	68.3
2014-04-12 23:20:00	3.7	49160	11.1	6664	2.289	79.3	42497	2.428	86.4
2014-04-14 12:30:00	1.3	114265	11.1	34369	2.712	75.5	79896	4.565	69.9
2014-04-25 15:20:00	3.1	34545	6.6	358	0.163	97.5	34188	1.953	99.0
2014-04-29 7:20:00	3.5	275033	26.6	104117	11.122	58.1	170916	9.765	62.1
2014-05-13 3:30:00	0.8	96992	81.9	48537	15.67	80.9	48455	2.768	50.0
2014-05-13 19:00:00	0.4	26573	35.4	20538	4.742	86.6	6035	0.345	22.7
2014-05-14 17:00:00	0.7	67762	19.9	65941	11.805	40.8	1821	0.104	2.7
2014-05-15 10:30:00	0.4	118251	13.3	115485	4.577	65.6	2766	0.158	2.3
2014-05-20 8:10:00	0.6	19930	4.4	0		100.0	19930	1.139	100.0
2014-05-27 15:50:00	3.2	27902	46.5	0		100.0	27902	1.594	100.0
2014-06-02 23:30:00	6.3	38531	6.6	0		100.0	38531	2.201	100.0
2014-06-11 5:30:00	2.5	43846	50.9	1157	1.631	96.8	42688	2.439	97.4
2014-06-11 21:10:00	0.5	95664	42.1	20185	9.231	78.1	75478	4.312	78.9
2014-06-17 17:50:00	0.3	71748	57.6	14837	13.451	76.6	56911	3.251	79.3
2014-06-23 17:00:00	4.3	14615	13.3	0		100.0	14615	0.835	100.0
2014-06-24 12:00:00	0.3	22587	8.9	0		100.0	22587	1.290	100.0
2014-06-25 17:40:00	0.9	111607	17.7	14098	4.25	76.0	97509	5.571	87.4
2014-06-29 19:00:00	3.8	25245	24.4	0		100.0	25245	1.442	100.0
2014-07-07 2:20:00	3.6	70419	17.7	1122	0.936	94.7	69297	3.959	98.4
2014-07-07 14:20:00	0.4	34545	46.5	6768	7.736	83.4	27777	1.587	80.4
2014-07-08 11:30:00	0.8	71748	70.9	17553	16.95	76.1	54195	3.096	75.5
2014-07-13 5:10:00	3.8	71748	62.0	3935	3.614	94.2	67813	3.874	94.5
2014-07-15 1:20:00	1.6	77062	48.7	7631	4.25	91.3	69431	3.967	90.1
2014-07-19 13:50:00	2.9	39860	6.6	0		100.0	39860	2.277	100.0
2014-07-20 14:40:00	0.7	19930	13.3	0		100.0	19930	1.139	100.0
2014-07-27 18:50:00	4.7	223215	19.9	61244	5.938	70.2	161970	9.254	72.6
2014-08-04 16:20:00	7.3	71748	59.8	31236	13.692	77.1	40512	2.315	56.5
2014-08-11 22:50:00	6.3	155453	48.7	43143	9.231	81.1	112310	6.417	72.2
2014-09-01 21:00:00	2.5	15944	6.6	0		100.0	15944	0.911	100.0
2014-09-02 11:30:00	0.6	74405	75.3	12778	9.611	87.2	61627	3.521	82.8
2014-09-05 19:00:00	3.1	224544	57.6	74504	8.666	84.9	150040	8.572	66.8
2014-09-10 15:50:00	4.1	118251	24.4	25899	3.155	87.0	92352	5.276	78.1
2014-09-15 15:30:00	2.0	25245	6.6	0		100.0	25245	1.442	100.0
2014-09-20 21:40:00	4.3	103635	24.4	21341	5.764	76.3	82294	4.702	79.4
2014-10-03 13:30:00	11.7	59790	8.9	0		100.0	59790	3.416	100.0
2014-10-06 22:20:00	2.8	23916	6.6	0		100.0	23916	1.366	100.0

Starting Date and Time	Antecedent Dry Period (Days)	Total Inflow Volume (L)	Peak Inflow (L/s)	Total Outflow Volume (L)	Peak Outflow (L/s)	Peak Reduction (%)	Estimated Volume Reduction		
							(L)	Normalized (L/m^2)	(%)
2014-10-07 16:20:00	0.3	82377	13.3	2183	1.044	92.1	80194	4.582	97.4
2014-10-14 22:40:00	6.1	15944	6.6	0		100.0	15944	0.911	100.0
2014-10-16 16:50:00	1.5	71748	39.9	9021	6.646	83.3	62727	3.584	87.4
2014-10-20 13:40:00	0.3	13287	6.6	0		100.0	13287	0.759	100.0
2014-10-27 22:20:00	6.1	13287	6.6	0		100.0	13287	0.759	100.0
2014-10-31 4:40:00	2.5	89020	6.6	0		100.0	89020	5.086	100.0
2014-11-04 16:00:00	0.4	19930	4.4	0		100.0	19930	1.139	100.0
2014-11-06 17:20:00	1.9	17273	4.4	0		100.0	17273	0.987	100.0
2014-11-16 21:40:00	3.2	46503	4.4	0		100.0	46503	2.657	100.0
2014-11-22 17:40:00	2.9	14615	6.6	0		100.0	14615	0.835	100.0
2014-11-24 0:00:00	0.5	130209	19.9	24656	5.248	73.7	105552	6.031	81.1
2014-12-11 3:30:00	3.8	73076	4.4	0		100.0	73076	4.175	100.0
2014-12-16 10:20:00	4.0	26573	4.4	0		100.0	26573	1.518	100.0
2014-12-24 20:20:00	0.7	39860	13.3	0		100.0	39860	2.277	100.0
2015-01-03 13:00:00	3.2	111607	11.1	0		100.0	111607	6.376	100.0
2015-01-29 13:10:00	10.7	46503	6.6	0		100.0	46503	2.657	100.0
2015-02-03 10:30:00	0.6	27902	6.6	0		100.0	27902	1.594	100.0
2015-02-07 6:40:00	0.9	25245	4.4	0		100.0	25245	1.442	100.0
2015-02-21 9:10:00	9.5	42517	6.6	0		100.0	42517	2.429	100.0
2015-03-03 11:50:00	9.2	38531	4.4	0		100.0	38531	2.201	100.0
2015-03-12 14:50:00	8.7	0		4735	0.457		-4735	-0.271	
2015-03-13 15:20:00	0.8	0		1991	0.227		-1991	-0.114	
2015-03-15 12:50:00	0.5	0		6310	0.544		-6310	-0.361	
2015-03-21 1:40:00	3.8	13287	4.4	0		100.0	13287	0.759	100.0
2015-03-25 11:10:00	4.3	21259	8.9	0		100.0	21259	1.215	100.0
2015-04-02 18:20:00	7.3	21259	13.3	0		100.0	21259	1.215	100.0
2015-04-03 17:50:00	0.9	18601	6.6	0		100.0	18601	1.063	100.0
2015-04-08 10:20:00	3.0	98321	19.9	18881	4.412	77.9	79439	4.539	80.8
2015-04-09 14:50:00	1.0	107621	35.4	45592	9.611	72.9	62029	3.544	57.6
2015-04-13 16:40:00	3.3	29231	13.3	0		100.0	29231	1.670	100.0
2015-04-19 22:40:00	2.8	132866	19.9	80734	3.614	81.9	52132	2.978	39.2
2015-04-21 11:50:00	0.7	47832	19.9	16455	2.018	89.9	31377	1.793	65.6
2015-05-11 19:50:00	1.8	17273	13.3	0		100.0	17273	0.987	100.0
2015-05-30 12:50:00	5.1	317550	66.4	24422	5.248	92.1	293127	16.747	92.3
2015-06-05 14:10:00	4.7	77062	86.4	18829	14.67	83.0	58234	3.327	75.6
2015-06-07 20:10:00	2.2	134195	53.1	32563	15.923	70.0	101632	5.807	75.7
2015-06-10 10:50:00	0.9	77062	73.1	48945	30.942	57.7	28117	1.606	36.5
2015-06-12 3:50:00	1.3	66433	35.4	12557	4.909	86.1	53876	3.078	81.1
2015-06-14 7:50:00	0.8	35874	6.6	571	0.298	95.5	35303	2.017	98.4

Starting Date and Time	Antecedent Dry Period (Days)	Total Inflow Volume (L)	Peak Inflow (L/s)	Total Outflow Volume (L)	Peak Outflow (L/s)	Peak Reduction (%)	Estimated Volume Reduction		
							(L)	Normalized (L/m^2)	(%)
2015-06-16 2:40:00	1.4	81048	39.9	29134	9.231	76.8	51915	2.966	64.1
2015-06-22 18:10:00	6.3	43846	33.2	326	0.544	98.4	43519	2.486	99.3
2015-06-27 10:40:00	4.0	358738	24.4	135802	11.122	54.3	222936	12.737	62.1
2015-07-07 12:40:00	7.9	96992	59.8	12325	6.826	88.6	84668	4.837	87.3
2015-07-14 19:30:00	0.4	19930	17.7	0		100.0	19930	1.139	100.0
2015-07-17 10:40:00	2.6	30559	8.9	0		100.0	30559	1.746	100.0
2015-07-17 23:30:00	0.4	73076	66.4	14252	8.666	87.0	58825	3.361	80.5
2015-07-19 15:20:00	1.3	46503	50.9	39243	25.599	49.7	7260	0.415	15.6

Table D-2: Hydrologic Summary of Rainfall Events for LV-4

Starting Date and Time	Antecedent Dry Period (Days)	Total Inflow Volume (L)	Peak Inflow (L/s)	Total Outflow Volume (L)	Peak Outflow (L/s)	Peak Reduction (%)	Estimated Volume Reduction		
							(L)	Normalized (L/m^2)	(%)
2012-09-04 8:40:00	1.0	36779	26.5	0		100.0	36779	8.927	100.0
2012-09-06 6:10:00	1.0	3429	2.1	0		100.0	3429	0.832	100.0
2012-09-08 0:10:00	1.6	59844	17.1	0		100.0	59844	14.525	100.0
2012-09-14 11:10:00	5.9	12779	3.1	0		100.0	12779	3.102	100.0
2012-09-18 4:10:00	1.6	26805	6.2	0		100.0	26805	6.506	100.0
2012-09-21 23:40:00	0.9	26805	4.2	0		100.0	26805	6.506	100.0
2012-10-05 21:40:00	13.5	13714	2.6	0		100.0	13714	3.329	100.0
2012-10-13 17:00:00	1.7	28987	3.6	0		100.0	28987	7.036	100.0
2012-10-17 7:30:00	1.7	4052	1.6	0		100.0	4052	0.983	100.0
2012-10-18 14:30:00	1.1	16520	4.7	0		100.0	16520	4.010	100.0
2012-10-19 22:00:00	1.0	6234	1.6	0		100.0	6234	1.513	100.0
2012-10-23 0:40:00	2.5	45818	5.7	0		100.0	45818	11.121	100.0
2012-10-27 5:40:00	0.4	33039	2.6	0		100.0	33039	8.019	100.0
2012-10-28 9:00:00	0.7	26182	2.6	0		100.0	26182	6.355	100.0
2012-10-29 13:30:00	0.3	19013	3.1	0		100.0	19013	4.615	100.0
2012-10-30 10:30:00	0.4	25870	16.1	0		100.0	25870	6.279	100.0
2012-10-31 14:30:00	0.3	6857	1.0	0		100.0	6857	1.664	100.0
2012-11-12 14:10:00	1.6	13091	1.6	0		100.0	13091	3.177	100.0
2012-12-02 3:20:00	1.3	18078	2.6	0		100.0	18078	4.388	100.0
2012-12-04 12:10:00	2.0	5610	1.6	0		100.0	5610	1.362	100.0
2012-12-08 8:10:00	0.5	4675	1.6	0		100.0	4675	1.135	100.0
2012-12-09 17:40:00	1.3	17766	2.6	0		100.0	17766	4.312	100.0
2012-12-16 8:10:00	6.0	6857	3.1	0		100.0	6857	1.664	100.0
2012-12-20 17:00:00	4.1	16831	2.1	0		100.0	16831	4.085	100.0
2012-12-26 20:00:00	1.8	10909	1.6	0		100.0	10909	2.648	100.0

Starting Date and Time	Antecedent Dry Period (Days)	Total Inflow Volume (L)	Peak Inflow (L/s)	Total Outflow Volume (L)	Peak Outflow (L/s)	Peak Reduction (%)	Estimated Volume Reduction		
							(L)	Normalized (L/m^2)	(%)
2012-12-29 4:50:00	0.5	7481	1.0	0		100.0	7481	1.816	100.0
2012-12-30 7:00:00	0.7	4675	1.6	0		100.0	4675	1.135	100.0
2013-01-11 4:00:00	0.9	9974	1.6	0		100.0	9974	2.421	100.0
2013-01-13 3:00:00	1.4	49870	6.2	0		100.0	49870	12.104	100.0
2013-01-13 20:40:00	0.5	5610	2.6	0		100.0	5610	1.362	100.0
2013-01-25 13:30:00	5.4	5610	1.0	0		100.0	5610	1.362	100.0
2013-01-28 3:30:00	1.8	14961	1.6	0		100.0	14961	3.631	100.0
2013-01-29 10:00:00	0.8	28364	3.1	0		100.0	28364	6.884	100.0
2013-01-30 8:50:00	0.3	5922	2.1	6503.4	0.388	81.3	-581	-0.141	-9.8
2013-02-02 8:00:00	2.0	5299	3.1	0		100.0	5299	1.286	100.0
2013-02-07 18:30:00	4.5	5610	1.0	0		100.0	5610	1.362	100.0
2013-02-09 8:10:00	0.9	10286	1.6	0		100.0	10286	2.497	100.0
2013-02-11 2:10:00	0.7	8416	1.6	0		100.0	8416	2.043	100.0
2013-02-14 17:20:00	3.1	3429	1.0	0		100.0	3429	0.832	100.0
2013-02-16 17:00:00	1.8	3740	1.0	0		100.0	3740	0.908	100.0
2013-02-19 5:00:00	0.9	15273	2.1	0		100.0	15273	3.707	100.0
2013-02-26 19:20:00	2.5	73871	4.2	19600.8	0.735	82.3	54270	13.172	73.5
2013-02-28 12:40:00	0.3	0		231	0.043		-231	-0.056	
2013-03-03 7:20:00	2.3	4675	1.6	0		100.0	4675	1.135	100.0
2013-03-11 6:50:00	2.8	15896	1.6	0		100.0	15896	3.858	100.0
2013-03-18 17:50:00	4.9	6857	1.6	0		100.0	6857	1.664	100.0
2013-03-31 22:30:00	10.2	3740	4.7	0		100.0	3740	0.908	100.0
2013-04-08 15:20:00	7.7	16831	4.7	0		100.0	16831	4.085	100.0
2013-04-09 15:10:00	0.7	55169	8.3	7537.8	0.388	95.3	47631	11.561	86.3
2013-04-11 6:00:00	0.3	45507	5.2	26008.2	0.735	85.9	19499	4.733	42.8
2013-04-13 9:00:00	0.5	4987	1.6	0		100.0	4987	1.210	100.0
2013-04-17 22:30:00	1.3	5299	1.6	0		100.0	5299	1.286	100.0
2013-04-24 10:30:00	4.3	22442	2.6	0		100.0	22442	5.447	100.0
2013-04-28 17:30:00	2.1	19013	2.1	0		100.0	19013	4.615	100.0
2013-05-10 8:50:00	0.7	34286	8.3	0		100.0	34286	8.322	100.0
2013-05-15 4:10:00	0.7	4987	6.2	0		100.0	4987	1.210	100.0
2013-05-20 21:40:00	5.6	11221	5.7	0		100.0	11221	2.724	100.0
2013-05-22 14:30:00	1.5	3429	5.2	0		100.0	3429	0.832	100.0
2013-05-28 5:50:00	3.6	6234	1.0	0		100.0	6234	1.513	100.0
2013-05-28 16:20:00	0.3	42702	13.0	0		100.0	42702	10.364	100.0
2013-05-31 17:00:00	1.1	6234	3.1	0		100.0	6234	1.513	100.0
2013-06-02 0:50:00	0.4	5922	2.1	0		100.0	5922	1.437	100.0
2013-06-02 11:10:00	0.3	5610	3.6	0		100.0	5610	1.362	100.0
2013-06-06 13:30:00	4.0	11533	1.6	0		100.0	11533	2.799	100.0

Starting Date and Time	Antecedent Dry Period (Days)	Total Inflow Volume (L)	Peak Inflow (L/s)	Total Outflow Volume (L)	Peak Outflow (L/s)	Peak Reduction (%)	Estimated Volume Reduction		
							(L)	Normalized (L/m^2)	(%)
2013-06-10 7:50:00	1.8	51429	11.4	1475.4	0.303	97.3	49953	12.125	97.1
2013-06-13 9:30:00	2.3	8104	3.1	0		100.0	8104	1.967	100.0
2013-06-18 5:10:00	1.7	10597	4.7	0		100.0	10597	2.572	100.0
2013-06-22 12:40:00	4.2	6545	4.2	0		100.0	6545	1.589	100.0
2013-06-23 17:20:00	0.9	3429	5.2	0		100.0	3429	0.832	100.0
2013-06-28 4:00:00	1.7	10286	3.1	0		100.0	10286	2.497	100.0
2013-07-01 5:30:00	2.5	4364	1.6	0		100.0	4364	1.059	100.0
2013-07-03 12:00:00	2.1	6234	6.8	0		100.0	6234	1.513	100.0
2013-07-03 23:40:00	0.5	8727	5.2	0		100.0	8727	2.118	100.0
2013-07-05 6:30:00	0.6	23688	8.3	0		100.0	23688	5.750	100.0
2013-07-07 0:30:00	1.3	8727	4.2	0		100.0	8727	2.118	100.0
2013-07-07 16:40:00	0.6	30234	34.3	0		100.0	30234	7.338	100.0
2013-07-08 16:10:00	0.6	127170	93.0	151521	70.04	24.7	-24351	-5.911	-19.1
2013-07-09 20:00:00	0.4	0		1800.6	0.303		-1801	-0.437	
2013-07-19 17:10:00	9.3	19636	12.5	0		100.0	19636	4.766	100.0
2013-07-27 15:30:00	7.6	7792	6.8	0		100.0	7792	1.891	100.0
2013-07-31 15:30:00	3.8	43013	4.7	0		100.0	43013	10.440	100.0
2013-08-02 15:10:00	1.2	5610	2.1	0		100.0	5610	1.362	100.0
2013-08-26 3:40:00	0.3	24000	17.1	0		100.0	24000	5.825	100.0
2013-08-27 17:30:00	0.4	31481	8.3	0		100.0	31481	7.641	100.0
2013-09-07 7:50:00	4.7	30857	6.2	0		100.0	30857	7.490	100.0
2013-09-11 15:30:00	4.0	21195	9.4	0		100.0	21195	5.144	100.0
2013-09-20 22:00:00	4.3	52987	6.2	0		100.0	52987	12.861	100.0
2013-09-30 4:30:00	0.3	3740	1.6	0		100.0	3740	0.908	100.0
2013-10-04 0:30:00	3.5	15273	5.7	0		100.0	15273	3.707	100.0
2013-10-06 23:40:00	0.6	14026	3.1	0		100.0	14026	3.404	100.0
2013-10-13 6:20:00	3.6	16831	5.7	0		100.0	16831	4.085	100.0
2013-10-16 0:40:00	2.3	7792	4.2	0		100.0	7792	1.891	100.0
2013-10-17 16:20:00	1.1	11533	3.1	0		100.0	11533	2.799	100.0
2013-10-19 11:10:00	1.7	10909	1.6	0		100.0	10909	2.648	100.0
2013-10-21 18:00:00	1.9	11221	1.6	0		100.0	11221	2.724	100.0
2013-10-26 5:50:00	0.5	12468	1.0	0		100.0	12468	3.026	100.0
2013-10-31 3:20:00	1.2	21195	4.2	0		100.0	21195	5.144	100.0
2013-10-31 17:10:00	0.3	8104	2.6	0		100.0	8104	1.967	100.0
2013-11-02 9:10:00	1.2	3117	1.0	0		100.0	3117	0.757	100.0
2013-11-06 17:10:00	4.0	7792	1.6	0		100.0	7792	1.891	100.0
2013-11-17 2:40:00	5.9	7169	3.1	0		100.0	7169	1.740	100.0
2013-11-17 20:10:00	0.6	14961	6.8	0		100.0	14961	3.631	100.0
2013-11-21 6:00:00	3.2	4052	3.1	0		100.0	4052	0.983	100.0

Starting Date and Time	Antecedent Dry Period (Days)	Total Inflow Volume (L)	Peak Inflow (L/s)	Total Outflow Volume (L)	Peak Outflow (L/s)	Peak Reduction (%)	Estimated Volume Reduction		
							(L)	Normalized (L/m²)	(%)
2013-11-21 22:20:00	0.6	8416	1.0	0		100.0	8416	2.043	100.0
2013-11-26 20:10:00	4.2	7481	1.0	0		100.0	7481	1.816	100.0
2013-12-15 9:30:00	0.6	5922	1.0	0		100.0	5922	1.437	100.0
2013-12-19 23:40:00	1.1	67948	4.2	2404.8	0.154	96.3	65544	15.909	96.5
2014-01-05 14:00:00	0.4	28052	2.1	0		100.0	28052	6.809	100.0
2014-01-10 0:50:00	0.7	9039	2.1	0		100.0	9039	2.194	100.0
2014-01-11 0:30:00	0.6	14649	1.6	0		100.0	14649	3.556	100.0
2014-01-26 5:00:00	0.9	10909	2.1	0		100.0	10909	2.648	100.0
2014-02-01 10:50:00	5.3	23065	2.1	0		100.0	23065	5.598	100.0
2014-02-04 23:50:00	3.0	5299	1.0	0		100.0	5299	1.286	100.0
2014-02-06 9:50:00	0.3	3429	1.6	0		100.0	3429	0.832	100.0
2014-02-18 0:50:00	8.5	6234	1.6	0		100.0	6234	1.513	100.0
2014-02-20 15:50:00	2.3	29611	4.7	0		100.0	29611	7.187	100.0
2014-03-02 10:40:00	0.4	3117	1.0	0		100.0	3117	0.757	100.0
2014-03-10 6:00:00	5.6	4364	1.0	0		100.0	4364	1.059	100.0
2014-03-12 9:20:00	2.0	6234	1.0	0		100.0	6234	1.513	100.0
2014-03-19 15:50:00	6.0	7481	2.1	0		100.0	7481	1.816	100.0
2014-03-27 21:40:00	5.6	4987	1.0	0		100.0	4987	1.210	100.0
2014-04-04 10:10:00	7.0	14338	2.6	0		100.0	14338	3.480	100.0
2014-04-07 17:00:00	2.9	27117	2.6	0		100.0	27117	6.582	100.0
2014-04-12 23:20:00	3.7	11533	2.6	0		100.0	11533	2.799	100.0
2014-04-14 12:30:00	1.4	11533	2.6	0		100.0	11533	2.799	100.0
2014-04-14 23:50:00	0.4	15273	2.6	0		100.0	15273	3.707	100.0
2014-04-25 15:20:00	3.1	8104	1.6	0		100.0	8104	1.967	100.0
2014-04-29 7:20:00	3.5	64520	6.2	14636.4	1.403	77.5	49883	12.108	77.3
2014-05-13 3:30:00	0.8	22753	19.2	0		100.0	22753	5.523	100.0
2014-05-13 19:00:00	0.6	6234	8.3	0		100.0	6234	1.513	100.0
2014-05-14 17:00:00	0.8	15896	4.7	0		100.0	15896	3.858	100.0
2014-05-15 10:30:00	0.7	27429	3.1	0		100.0	27429	6.657	100.0
2014-05-20 8:10:00	0.6	4675	1.0	0		100.0	4675	1.135	100.0
2014-05-27 15:50:00	3.2	6545	10.9	0		100.0	6545	1.589	100.0
2014-06-02 23:30:00	6.3	9039	1.6	0		100.0	9039	2.194	100.0
2014-06-05 15:50:00	2.2	8727	5.7	0		100.0	8727	2.118	100.0
2014-06-11 5:30:00	2.5	10286	11.9	0		100.0	10286	2.497	100.0
2014-06-11 21:10:00	0.5	22442	9.9	0		100.0	22442	5.447	100.0
2014-06-17 17:50:00	0.3	16831	13.5	0		100.0	16831	4.085	100.0
2014-06-23 17:00:00	4.3	3429	3.1	0		100.0	3429	0.832	100.0
2014-06-24 12:00:00	0.3	5299	2.1	0		100.0	5299	1.286	100.0
2014-06-25 17:40:00	0.9	26182	4.2	0		100.0	26182	6.355	100.0

Starting Date and Time	Antecedent Dry Period (Days)	Total Inflow Volume (L)	Peak Inflow (L/s)	Total Outflow Volume (L)	Peak Outflow (L/s)	Peak Reduction (%)	Estimated Volume Reduction		
							(L)	Normalized (L/m^2)	(%)
2014-06-29 19:00:00	3.8	5922	5.7	0		100.0	5922	1.437	100.0
2014-07-07 2:20:00	3.6	16520	4.2	0		100.0	16520	4.010	100.0
2014-07-07 14:20:00	0.4	8104	10.9	0		100.0	8104	1.967	100.0
2014-07-08 11:30:00	0.9	16831	16.6	0		100.0	16831	4.085	100.0
2014-07-13 5:10:00	3.8	16831	14.5	0		100.0	16831	4.085	100.0
2014-07-15 1:20:00	1.6	18078	11.4	0		100.0	18078	4.388	100.0
2014-07-19 13:50:00	2.9	9351	1.6	0		100.0	9351	2.270	100.0
2014-07-20 14:40:00	0.7	4675	3.1	0		100.0	4675	1.135	100.0
2014-07-27 18:50:00	4.7	52364	4.7	5895.6	0.79	83.1	46468	11.279	88.7
2014-08-04 16:20:00	7.2	16831	14.0	0		100.0	16831	4.085	100.0
2014-08-11 22:50:00	6.3	36468	11.4	0		100.0	36468	8.851	100.0
2014-09-01 21:00:00	2.5	3740	1.6	0		100.0	3740	0.908	100.0
2014-09-02 11:30:00	0.6	17455	17.7	0		100.0	17455	4.237	100.0
2014-09-05 19:00:00	3.2	52987	13.5	15179.4	1.272	90.6	37808	9.177	71.4
2014-09-10 15:50:00	4.1	27740	5.7	0		100.0	27740	6.733	100.0
2014-09-15 15:30:00	2.0	5922	1.6	0		100.0	5922	1.437	100.0
2014-09-20 21:40:00	4.3	24312	5.7	0		100.0	24312	5.901	100.0
2014-10-03 13:30:00	11.7	14026	2.1	0		100.0	14026	3.404	100.0
2014-10-06 22:20:00	2.8	5610	1.6	0		100.0	5610	1.362	100.0
2014-10-07 16:20:00	0.3	19325	3.1	0		100.0	19325	4.690	100.0
2014-10-14 22:40:00	6.1	3740	1.6	0		100.0	3740	0.908	100.0
2014-10-16 16:50:00	1.5	16831	9.4	0		100.0	16831	4.085	100.0
2014-10-20 13:40:00	0.3	3117	1.6	0		100.0	3117	0.757	100.0
2014-10-27 22:20:00	6.1	3117	1.6	0		100.0	3117	0.757	100.0
2014-10-31 4:40:00	2.5	20883	1.6	0		100.0	20883	5.069	100.0
2014-11-04 16:00:00	0.4	4675	1.0	0		100.0	4675	1.135	100.0
2014-11-06 17:20:00	1.9	4052	1.0	0		100.0	4052	0.983	100.0
2014-11-16 21:40:00	3.2	10909	1.0	0		100.0	10909	2.648	100.0
2014-11-22 17:40:00	2.9	3429	1.6	0		100.0	3429	0.832	100.0
2014-11-24 0:00:00	0.5	30546	4.7	0		100.0	30546	7.414	100.0
2014-12-11 3:30:00	3.8	17143	1.0	0		100.0	17143	4.161	100.0
2014-12-16 10:20:00	4.0	6234	1.0	0		100.0	6234	1.513	100.0
2014-12-24 20:20:00	0.7	9351	3.1	0		100.0	9351	2.270	100.0
2015-01-03 13:00:00	3.2	26182	2.6	0		100.0	26182	6.355	100.0
2015-01-29 13:10:00	10.7	10909	1.6	0		100.0	10909	2.648	100.0
2015-02-03 10:30:00	0.6	6545	1.6	0		100.0	6545	1.589	100.0
2015-02-07 6:40:00	0.9	5922	1.0	0		100.0	5922	1.437	100.0
2015-02-21 9:10:00	9.5	9974	1.6	0		100.0	9974	2.421	100.0
2015-03-03 11:50:00	9.2	9039	1.0	0		100.0	9039	2.194	100.0

Starting Date and Time	Antecedent Dry Period (Days)	Total Inflow Volume (L)	Peak Inflow (L/s)	Total Outflow Volume (L)	Peak Outflow (L/s)	Peak Reduction (%)	Estimated Volume Reduction		
							(L)	Normalized (L/m^2)	(%)
2015-03-21 1:40:00	4.0	3117	1.0	0		100.0	3117	0.757	100.0
2015-03-25 11:10:00	4.3	4987	2.1	0		100.0	4987	1.210	100.0
2015-04-02 18:20:00	7.3	4987	3.1	0		100.0	4987	1.210	100.0
2015-04-03 17:50:00	0.9	4364	1.6	0		100.0	4364	1.059	100.0
2015-04-08 10:20:00	3.0	23065	4.7	0		100.0	23065	5.598	100.0
2015-04-09 14:50:00	1.0	25247	8.3	0		100.0	25247	6.128	100.0
2015-04-13 16:40:00	3.3	6857	3.1	0		100.0	6857	1.664	100.0
2015-04-19 22:40:00	2.8	31169	4.7	539.4	0.093	98.0	30630	7.434	98.3
2015-04-21 11:50:00	0.8	10909	4.7	0		100.0	10909	2.648	100.0
2015-05-11 19:50:00	1.8	4052	3.1	0		100.0	4052	0.983	100.0
2015-05-30 12:50:00	5.1	74494	15.6	0		100.0	74494	18.081	100.0
2015-06-05 14:10:00	4.7	18078	20.3	0		100.0	18078	4.388	100.0
2015-06-07 20:10:00	2.2	31481	12.5	0		100.0	31481	7.641	100.0
2015-06-10 10:50:00	0.9	18078	17.1	0		100.0	18078	4.388	100.0
2015-06-12 3:50:00	1.4	15584	8.3	0		100.0	15584	3.783	100.0
2015-06-14 7:50:00	0.8	8416	1.6	0		100.0	8416	2.043	100.0
2015-06-16 2:40:00	1.4	18701	9.4	0		100.0	18701	4.539	100.0
2015-06-22 18:10:00	6.3	10286	7.8	0		100.0	10286	2.497	100.0
2015-06-27 10:40:00	4.0	84156	5.7	19193.4	1.47	74.3	64963	15.768	77.2
2015-07-07 12:40:00	8.8	22753	14.0	0		100.0	22753	5.523	100.0
2015-07-14 19:30:00	0.4	4675	4.2	0		100.0	4675	1.135	100.0
2015-07-17 10:40:00	2.6	7169	2.1	0		100.0	7169	1.740	100.0
2015-07-17 23:30:00	0.4	17143	15.6	0		100.0	17143	4.161	100.0
2015-07-19 15:20:00	1.3	10909	11.9	0		100.0	10909	2.648	100.0

3 WATER QUALITY PERFORMANCE

Table D-3: EMC Summary for All Events for LV-1

Starting Date and time	TSS (mg/L)	TP (mg/L)	PO4 (mg/L)	NO2+NO3 (mg/L)	TKN (mg/L)	Cd (µg/L)	Cu (µg/L)	Fe (µg/L)	Pb[1] (µg/L)	Ni[1] (µg/L)	Zn (µg/L)
2012-10-13	16	0.71	0.59	0.05	1.2	0.33	10.7	208	3.44	1	82.7
2012-10-23	14	0.32	0.22	0.05	0.2	0.11	5.9	176	2.31	0.8	46.5
2012-12-09	11	0.10	0.070	0.42	1.2	0.10	5.2	205	2.68	0.7	56.1
2013-04-09	160	0.37	0.084	0.42	2.3	0.73	31.4	1270	19.2	3	200
2013-04-24	68	0.24	0.048	0.29	1.7	0.17	15.4	596	6.52	1.5	68.9
2013-05-20	89	0.67	0.21	0.05	4.2	0.47	23	720	7.38	2.3	98
2013-05-22	170	0.47	0.18	0.25	3.5	0.34	24	1370	15.9	3.1	148
2013-05-31	120	0.48	0.17	0.11	3.9	0.37	23.8	656	7.7	1.9	88.5
2013-06-02	30	0.2	0.19	0.21	1.1	0.15	10.1	194	2.12	0.8	24.8
2013-06-06	37	0.28	0.16	0.36	1.6	0.15	11.7	377	3.76	0.8	46.7
2013-06-13	99	0.47	0.069	0.29	2.5	0.29	17	951	9.66	1.6	88.3
2013-06-16	180	0.26	0.095	0.29	1.8	0.48	12.7	1080	12	1.7	99.9
2013-06-22	320	0.73	0.14	0.3	4.6	0.46	23.7	3220	25.1	4.8	209
2013-07-03	21	0.49	0.17	0.97	2.8	0.19	21	1050	11.6	2.2	91.7
2013-07-07	7	0.21	0.1	0.26	0.65	0.2	7.1	156	1.4	0.5	24.7
2013-07-08	170	0.4	0.16	0.92	1.6	0.33	23.8	996	14.2	2.3	113
2013-07-27	51	0.6	0.28	0.23	2.9	0.32	26.1	718	7.08	2.5	83.8
2013-08-26	98	0.48	0.16	0.54	3.4	0.26	21.9	1090	11.6	2.5	86.2
2013-08-27	17	0.17	0.1	0.46	0.95	0.16	8.4	166	2.08	0.8	25.9
2013-09-12	8	0.14	0.09	0.5	0.86	0.09	15.4	151	1.84	0.8	30.1
2013-10-04	24	0.34	0.2	0.12	1.1	0.11	17.7	189	2.58	0.7	38.4
2013-10-07	6	0.24	0.24	0.05	0.64	0.07	11.5	122	1.1	0.5	26.4
2013-10-17	14	0.78	0.62	0.05	3.1	0.07	7.4	173	1.85	0.5	30.9
2013-10-31	11	0.21	0.15	0.05	0.43	0.07	8.1	127	2.43	0.3	27.8
2014-03-19	63	0.57	0.38	0.7	5.8	0.25	31	1140	19.1	5	125
2014-04-04	84	0.41	0.23	0.83	1.7	0.6	30	3300	44	7.1	280
2014-04-07	50	0.21	0.12	0.54	1.2	0.26	16	1600	20	3.3	130
2014-04-13	81	0.18	0.063	0.65	1.9	0.24	18	1700	16	3.8	110
2014-04-14	66	0.24	0.073	0.17	1.3	0.22	16.5	701	11.5	2.2	90.9
2014-04-29	54	0.16	0.072	0.49	1.2	0.12	12.8	476	8.8	1.5	66.1
2014-05-13	200	0.36	0.066	0.32	1.9	0.22	24.7	1290	14.2	3.5	114

13/05/2014b	93	0.23	0.086	0.36	1.5	0.14	22.2	614	7.67	2.1	59.9
2014-05-14	27	0.25	0.12	0.62	1.4	0.23	14.7	303	3.44	1.6	37.8
2014-05-15	15	0.1	0.052	0.27	0.5	0.09	6.2	200	2.88	0.8	31.6
2014-06-17	530	0.79	0.14	0.18	5.3	0.46	46	3140	27.6	5.9	210
2014-06-25	72	0.25	0.054	0.34	1	0.18	15.1	834	5.86	1.9	58.1
2014-07-07	33	0.31	0.14	0.46	1.4	0.14	9.3	533	3.46	1.2	42.1
2014-08-11	42	0.23	0.12	0.31	0.99	0.14	16.2	477	4.21	1.3	42.6
2014-09-02	51	0.22	0.15	0.41	1.3	0.16	20.1	478	4.03	1.8	49.7
2014-09-05	8	0.14	0.12	0.42	0.43	0.12	13.6	178	1.34	0.6	28
2014-09-10	7	0.14	0.066	0.23	0.73	0.08	14.4	154	1.2	0.6	24.6
2014-09-21	19	0.16	0.078	0.18	0.79	0.19	11.4	224	2.26	0.6	22.1
2014-10-07	11	0.39	0.28	0.05	0.68	0.08	7.4	95	1.48	0.6	26.5
2015-03-11	90	0.79	0.55	0.76	6	0.5	19	1210	14	5	107
2015-04-08	93	0.3	0.068	0.2	1.4	0.33	18.6	840	13.2	2.7	101
2015-04-09	43	0.14	0.13	1.11	0.75	0.13	12.1	321	8.98	3.3	76.1
2015-04-19	27	0.16	0.023	0.05	0.72	0.09	14.6	377	8.11	2.4	58
2015-04-21	39	0.19	0.086	0.43	1.2	0.17	18.7	542	7.14	2	73.4
2015-06-27	21	0.17	0.069	0.41	0.5	0.13	7	269	2.76	1.2	34.2
2015-07-07	180	0.48	0.13	0.17	1.7	0.34	17.1	1280	9.3	3.8	89.5
count	50	50	50	50	50	50	50	50	50	50	50
average	74.800	0.339	0.159	0.358	1.830	0.233	16.714	764.74	8.761	2.068	78.49
median	46.500	0.255	0.125	0.305	1.350	0.185	15.700	537.50	7.110	1.750	67.50
25th percentile	17.500	0.193	0.074	0.180	0.883	0.123	11.425	201.25	2.605	0.800	35.10
75th percentile	92.250	**0.470**	0.178	0.460	2.200	0.328	21.675	1072.5	11.900	2.650	99.425
WQ Guideline	25	0.03	-	3[a]	-	0.2	5	300	1	25	20

[a] Water quality guideline for Nitrate used

Table D-3: EMC Summary for All Events for LV-2

Starting Date and time	Precipitation Depth (mm)	TSS (mg/L)	TP (mg/L)	PO4 (mg/L)	NO2+NO3 (mg/L)	TKN (mg/L)	Cd (µg/L)	Cu (µg/L)	Fe (µg/L)	Pb[1] (µg/L)	Ni[1] (µg/L)	Zn (µg/L)
2013-04-08 15:20:00	10.8	270	0.6	0.13	1.2	4.7	0.43	27.1	1160	30.9	2.6	190
2013-04-09 15:10:00	67.8	63	0.24	0.15	1.5	1.5	0.23	18.9	586	10.8	1.3	71
2013-04-24 10:30:00	14.4	38	0.22	0.1	0.47	1.3	0.2	16.8	437	4.92	0.8	41
2013-04-28 17:30:00	12.2	19	0.2	0.1	0.36	1	0.09	11.4	257	2.94	0.5	30.6
2013-05-10 8:50:00	22.0	56	0.34	0.12	0.74	2.7	0.17	17.2	588	7.68	1.3	55.5

2013-05-20 21:40:00	7.2	66	0.57	0.12	0.79	4.1	0.52	22.3	751	10.8	2	92
2013-05-31 17:00:00	4.0	100	0.59	0.33	0.23	2.5	0.16	18.7	1110	10.2	2.2	61
2013-06-13 9:30:00	5.2	31	0.31	0.15	0.69	1.9	0.14	13.2	299	2.93	1.3	30.9
2013-06-16 5:10:00	10.8	81	0.28	0.14	0.37	1.2	0.26	11.9	396	5.42	1	44.6
2013-07-07 0:30:00	5.6	670	1.3	0.14	0.3	4.2	0.86	40.7	5200	59.8	7.9	433
2013-07-19 17:10:00	12.6	64	0.42	0.23	1.6	2.6	0.23	23.3	381	7.85	2	75.3
2013-08-02 15:10:00	3.6	10	0.21	0.15	0.57	0.55	0.1	9.1	139	1.62	0.6	36.9
2013-08-26 3:40:00	15.4	110	0.37	0.13	0.55	3.2	0.16	21.7	1010	15.1	2.2	80.4
2013-08-27 17:30:00	20.2	9	0.21	0.13	0.8	1.2	0.12	13.7	120	1.58	0.6	27.5
2013-09-20 22:00:00	34.0	26	0.19	0.11	0.52	1.3	0.13	9.6	241	3.86	0.6	30.7
2013-10-31 3:20:00	13.6	16	0.2	0.15	0.37	0.84	0.09	16.5	216	2.78	0.5	35.3
2014-04-04 10:10:00	9.2	45	0.27	0.17	2.29	1.5	0.18	24	2200	11	3.4	120
2014-04-07 17:00:00	17.4	49	0.25	0.18	2.13	1.3	0.18	19	2000	10	2.6	97
2014-04-12 23:20:00	7.4	54	0.16	0.095	2.46	2	0.17	23	1100	9.9	1.9	69
2014-05-13 3:30:00	14.6	99	0.35	0.17	0.59	3.2	0.1	20.2	890	10.7	1.9	79.4
2014-05-13 19:00:00	4.0	40	0.24	0.11	0.59	1.5	0.11	23.1	497	6.11	1.3	46.7
2014-05-14 17:00:00	10.2	30	0.28	0.17	0.45	1.1	0.2	16.8	457	4.92	1.2	40.4
2014-05-15 10:30:00	17.8	13	0.15	0.11	0.91	1.1	0.12	13.5	295	2.5	1	39.5
2014-06-17 17:50:00	10.8	32	0.25	0.22	0.39	1.3	0.18	17.7	373	4.9	1.2	37.4
2014-06-25 17:40:00	16.8	12	0.17	0.074	0.46	0.95	0.08	11.5	191	1.78	0.8	38
2014-08-11 22:50:00	23.4	19	0.38	0.27	0.32	1.1	0.2	14.7	209	2.28	0.8	28
2014-09-02 11:30:00	11.2	60	0.23	0.15	0.65	1.6	0.18	22.7	441	6.28	1.2	47.3
2014-09-10 15:50:00	17.8	10	0.14	0.085	0.43	0.47	0.36	12.3	174	1.74	0.7	28.8
2014-09-20 21:40:00	15.6	15	0.27	0.15	0.48	0.98	0.21	18.4	118	2.1	0.6	28.6
2014-10-07 16:20:00	12.4	18	0.13	0.16	0.33	0.14	0.06	8.4	243	2.55	0.6	27.8
2014-11-24 0:00:00	19.6	36	0.48	0.35	0.32	1.2	0.13	11.1	488	5.75	1	74.5
2015-04-08 10:20:00	14.8	51	0.32	0.18	1.38	1.3	0.39	17.9	611	8.68	1.8	80
2015-04-09 14:50:00	16.2	48	0.22	0.16	1.92	0.95	0.19	16.4	416	6.12	1.2	65.3
2015-04-19 22:40:00	20.0	14	0.2	0.13	1.18	0.71	0.15	17.7	287	3.25	1.2	39.8
2015-04-21 11:50:00	7.2	35	0.16	0.13	1.53	1.1	0.14	18.3	483	6.15	1.6	54.3
2015-05-30 12:50:00	47.8	79	0.46	0.24	0.48	1.2	0.14	31.8	501	10.4	2	71

2015-06-27 10:40:00	54.0	8	0.2	0.12	0.36	0.53	0.16	7.8	136	1.31	0.8	24.8
2015-07-07 12:40:00	14.6	62	0.44	0.25	0.57	0.93	0.16	18.4	487	7.18	1.4	53
count	38	38	38	38	38	38	38	38	38	38	38	38
average	16.90	64.68	0.32	0.16	0.82	1.60	0.20	17.81	670.74	8.02	1.52	66.48
median	14.50	39.00	0.25	0.15	0.57	1.25	0.17	17.70	439.00	5.93	1.20	47.00
25th percentile	10.35	18.25	0.20	0.12	0.40	0.99	0.13	13.28	246.50	2.82	0.80	35.70
75th percentile	17.80	62.75	0.37	0.17	1.11	1.83	0.20	21.33	605.25	9.98	1.90	73.63
WQ Guideline	-	25	0.03	-	3[a]	-	0.2	5	300	1	25	20

[a] Water quality guideline for Nitrate used

Table D-3: EMC Summary for All Events for LV-4

Starting Date and time	Precipitation Depth (mm)	TSS (mg/L)	TP (mg/L)	PO4 (mg/L)	NO2+NO3 (mg/L)	TKN (mg/L)	Cd (µg/L)	Cu (µg/L)	Fe (µg/L)	Pb[1] (µg/L)	Ni[1] (µg/L)	Zn (µg/L)
2013-06-10 7:50:00	33.0	23	0.35	0.28	1.2	1.4	0.12	16.4	300	3.2	15.6	15.6
2013-07-08 16:10:00	81.6	60	0.76	0.66	1.1	2.9	0.33	26.2	556	5.2	17.3	26
2014-04-29 7:20:00	41.4	28	0.52	0.37	5.01	2	0.14	13.5	659	4.6	13.3	23
2014-07-27 18:50:00	33.6	12	0.19	0.16	1.88		0.15	14.1	223	2.1	13.5	14.3
2014-09-05 19:00:00	34.0	14	0.18	0.12	2.64	1.7	0.1	14.3	168	1.89	14.1	16
2015-06-27 10:40:00	54.0	13	0.32	0.22	1.69	0.82	0.1	12.8	320	1.98	11.1	12.4
count	6	6	6	6	6	6	6	6	6	6	6	6
average	46.27	25.00	72104.29	2523.65	34650.20	1677.96	845.69	25.00	46.27	72104.29	2523.65	34650.20
median	37.70	18.50	58753.57	2056.37	14907.90	231.01	1764.03	18.50	37.70	58753.57	2056.37	14907.90
25th percentile	33.70	13.25	52519.77	1838.19	8080.80	106.19	1672.03	13.25	33.70	52519.77	1838.19	8080.80
75th percentile	50.85	26.75	79247.18	2773.65	18189.90	369.74	1827.80	26.75	50.85	79247.18	2773.65	18189.90
WQ Guideline	-	25	0.03	-	3[a]	-	0.2	5	300	1	25	20

[a] Water quality guideline for Nitrate used

Table D-4: Water Quality Performance for Total Suspended Solids (TSS) for LV-2

Starting Date and Time	Effluent EMC (mg/L)	Precipitation Depth (mm)	Total Estimated Influent Volume (m^3)	Total Estimated Influent Load (g)	Total Measured Effluent Volume (m^3)	Total Measured Effluent Load (g)	Estimated Pollutant Load Reduction		
							(g)	Normalized (g/m^2)	(%)
2013-04-08 15:20:00	270	10.8	71.7	5273.5	11.9	3206.1	2067.3	0.1181	39.2
2013-04-09 15:10:00	63	67.8	450.4	33105.6	238.3	15012.6	18092.9	1.0337	54.7
2013-04-24 10:30:00	38	14.4	95.7	3348.2	30.2	1148.9	2199.3	0.1257	65.7

2013-04-28 17:30:00	19	12.2	81.0	2836.7	22.6	429.3	2407.3	0.1375	84.9
2013-05-10 8:50:00	56	22.0	146.2	5115.3	62.5	3498.8	1616.5	0.0924	31.6
2013-05-20 21:40:00	66	7.2	47.8	1674.1	4.9	320.9	1353.2	0.0773	80.8
2013-05-31 17:00:00	100	4.0	26.6	930.1	6.0	599.6	330.5	0.0189	35.5
2013-06-13 9:30:00	31	5.2	34.5	1209.1	3.0	93.7	1115.4	0.0637	92.3
2013-06-16 5:10:00	81	10.8	71.7	2511.2	22.0	1778.4	732.8	0.0419	29.2
2013-07-07 0:30:00	670	5.6	37.2	1302.1	1.0	646.4	655.7	0.0375	50.4
2013-07-19 17:10:00	64	12.6	83.7	2929.7	4.7	302.7	2626.9	0.1501	89.7
2013-08-02 15:10:00	10	3.6	23.9	837.1	0.0	0.0	837.1	0.0478	100.0
2013-08-26 3:40:00	110	15.4	102.3	3580.7	3.3	368.1	3212.7	0.1835	89.7
2013-08-27 17:30:00	9	20.2	134.2	4696.8	22.0	197.9	4498.9	0.2570	95.8
2013-09-20 22:00:00	26	34.0	225.9	7905.5	2.8	72.4	7833.1	0.4475	99.1
2013-10-31 3:20:00	16	13.6	90.3	3162.2	1.1	18.0	3144.2	0.1796	99.4
2014-04-04 10:10:00	45	9.2	61.1	4492.2	6.9	310.0	4182.2	0.2389	93.1
2014-04-07 17:00:00	49	17.4	115.6	8496.1	36.7	1797.0	6699.2	0.3827	78.8
2014-04-12 23:20:00	54	7.4	49.2	3613.3	6.7	359.8	3253.5	0.1859	90.0
2014-05-13 3:30:00	99	14.6	97.0	3394.7	48.5	4805.2	-1410.4	-0.0806	-41.5
2014-05-13 19:00:00	40	4.0	26.6	930.1	20.5	821.5	108.5	0.0062	11.7
2014-05-14 17:00:00	30	10.2	67.8	2371.7	65.9	1978.2	393.4	0.0225	16.6
2014-05-15 10:30:00	13	17.8	118.3	4138.8	115.5	1501.3	2637.5	0.1507	63.7
2014-06-17 17:50:00	32	10.8	71.7	2511.2	14.8	474.8	2036.4	0.1163	81.1
2014-06-25 17:40:00	12	16.8	111.6	3906.3	14.1	169.2	3737.1	0.2135	95.7
2014-08-11 22:50:00	19	23.4	155.5	5440.9	43.1	819.7	4621.1	0.2640	84.9
2014-09-02 11:30:00	60	11.2	74.4	2604.2	12.8	766.7	1837.5	0.1050	70.6
2014-09-10 15:50:00	10	17.8	118.3	4138.8	25.9	259.0	3879.8	0.2217	93.7
2014-09-20 21:40:00	15	15.6	103.6	3627.2	21.3	320.1	3307.1	0.1889	91.2
2014-10-07 16:20:00	18	12.4	82.4	2883.2	2.2	39.3	2843.9	0.1625	98.6
2014-11-24 0:00:00	36	19.6	130.2	9570.3	24.7	887.6	8682.7	0.4961	90.7
2015-04-08 10:20:00	51	14.8	98.3	7226.6	18.9	963.0	6263.6	0.3579	86.7
2015-04-09 14:50:00	48	16.2	107.6	7910.2	45.6	2188.4	5721.8	0.3269	72.3
2015-04-19 22:40:00	14	20.0	132.9	4650.3	80.7	1130.3	3520.0	0.2011	75.7

2015-04-21 11:50:00	35	7.2	47.8	1674.1	16.5	575.9	1098.2	0.0627	65.6
2015-05-30 12:50:00	79	47.8	317.5	11114.2	24.4	1929.4	9184.9	0.5248	82.6
2015-06-27 10:40:00	8	54.0	358.7	12555.8	135.8	1086.4	11469.4	0.6553	91.3
2015-07-07 12:40:00	62	14.6	97.0	3394.7	12.3	764.1	2630.6	0.1503	77.5
count	38	38	38	38	38	38	38	38	38
average	64.68	16.90	112.27	5027.96	32.37	1358.97	3668.99	0.2096	71.28
median	39.00	14.50	96.33	3597.01	19.71	705.27	2740.69	0.1566	81.87
25th percentile	18.25	10.35	68.76	2534.42	6.16	312.54	1419.02	0.0811	64.19
75th percentile	62.75	17.80	118.25	5233.92	35.06	1413.21	4419.73	0.2525	91.30
WQ Guideline	25	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Table D-4: Water Quality Performance for Total Suspended Solids (TSS) for LV-4

Starting Date and Time	Effluent EMC (mg/L)	Precipitation Depth (mm)	Total Estimated Influent Volume (m^3)	Total Estimated Influent Load (g)	Total Measured Effluent Volume (m^3)	Total Measured Effluent Load (g)	Estimated Pollutant Load Reduction		
							(g)	Normalized (g/m^2)	(%)
2013-06-10 7:50:00	23	33.0	51428.9	1800.0	1475.4	33.9	1766.1	0.4287	98.1
2013-07-08 16:10:00	60	81.6	127169.5	4450.9	151521.0	9091.3	-4640.3	-1.1263	-104.3
2014-04-29 7:20:00	28	41.4	64519.8	2258.2	14636.4	409.8	1848.4	0.4486	81.9
2014-07-27 18:50:00	12	33.6	52363.9	1832.7	5895.6	70.7	1762.0	0.4277	96.1
2014-09-05 19:00:00	14	34.0	52987.3	1854.6	15179.4	212.5	1642.0	0.3986	88.5
2015-06-27 10:40:00	13	54.0	84156.3	2945.5	19193.4	249.5	2696.0	0.6544	91.5
count	6	6	6	6	6	6	6	6	6
average	25.00	46.27	72104.29	2523.65	34650.20	1677.96	845.69	0.2053	58.65
median	18.50	37.70	58753.57	2056.37	14907.90	231.01	1764.03	0.4282	90.03
25th percentile	13.25	33.70	52519.77	1838.19	8080.80	106.19	1672.03	0.4058	83.52
75th percentile	26.75	50.85	79247.18	2773.65	18189.90	369.74	1827.80	0.4436	94.99
WQ Guideline	25	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Table D-5: Water Quality Performance for Total Phosphorus (TP) for LV-2

Starting Date and Time	Effluent EMC (mg/L)	Precipitation Depth (mm)	Total Estimated Influent Volume (m^3)	Total Estimated Influent Load (g)	Total Measured Effluent Volume (m^3)	Total Measured Effluent Load (g)	Estimated Pollutant Load Reduction		
							(g)	Normalized (g/m^2)	(%)
2013-04-08 15:20:00	0.6	10.8	71.7	19.4	11.9	7.1	12.2	0.00070	63.2

2013-04-09 15:10:00	0.24	67.8	450.4	121.6	238.3	57.2	64.4	0.00368	53.0
2013-04-24 10:30:00	0.22	14.4	95.7	24.9	30.2	6.7	18.2	0.00104	73.3
2013-04-28 17:30:00	0.2	12.2	81.0	21.1	22.6	4.5	16.6	0.00095	78.6
2013-05-10 8:50:00	0.34	22.0	146.2	38.0	62.5	21.2	16.8	0.00096	44.1
2013-05-20 21:40:00	0.57	7.2	47.8	12.4	4.9	2.8	9.7	0.00055	77.7
2013-05-31 17:00:00	0.59	4.0	26.6	6.9	6.0	3.5	3.4	0.00019	48.8
2013-06-13 9:30:00	0.31	5.2	34.5	9.0	3.0	0.9	8.0	0.00046	89.6
2013-06-16 5:10:00	0.28	10.8	71.7	18.7	22.0	6.1	12.5	0.00071	67.0
2013-07-07 0:30:00	1.3	5.6	37.2	9.7	1.0	1.3	8.4	0.00048	87.0
2013-07-19 17:10:00	0.42	12.6	83.7	21.8	4.7	2.0	19.8	0.00113	90.9
2013-08-02 15:10:00	0.21	3.6	23.9	6.2	0.0	0.0	6.2	0.00036	100.0
2013-08-26 3:40:00	0.37	15.4	102.3	26.6	3.3	1.2	25.4	0.00145	95.3
2013-08-27 17:30:00	0.21	20.2	134.2	34.9	22.0	4.6	30.3	0.00173	86.8
2013-09-20 22:00:00	0.19	34.0	225.9	58.7	2.8	0.5	58.2	0.00333	99.1
2013-10-31 3:20:00	0.2	13.6	90.3	23.5	1.1	0.2	23.3	0.00133	99.0
2014-04-04 10:10:00	0.27	9.2	61.1	16.5	6.9	1.9	14.6	0.00084	88.7
2014-04-07 17:00:00	0.25	17.4	115.6	31.2	36.7	9.2	22.0	0.00126	70.6
2014-04-12 23:20:00	0.16	7.4	49.2	13.3	6.7	1.1	12.2	0.00070	92.0
2014-05-13 3:30:00	0.35	14.6	97.0	25.2	48.5	17.0	8.2	0.00047	32.6
2014-05-13 19:00:00	0.24	4.0	26.6	6.9	20.5	4.9	2.0	0.00011	28.7
2014-05-14 17:00:00	0.28	10.2	67.8	17.6	65.9	18.5	-0.8	-0.00005	-4.8
2014-05-15 10:30:00	0.15	17.8	118.3	30.7	115.5	17.3	13.4	0.00077	43.7
2014-06-17 17:50:00	0.25	10.8	71.7	18.7	14.8	3.7	14.9	0.00085	80.1
2014-06-25 17:40:00	0.17	16.8	111.6	29.0	14.1	2.4	26.6	0.00152	91.7
2014-08-11 22:50:00	0.38	23.4	155.5	40.4	43.1	16.4	24.0	0.00137	59.4
2014-09-02 11:30:00	0.23	11.2	74.4	19.3	12.8	2.9	16.4	0.00094	84.8
2014-09-10 15:50:00	0.14	17.8	118.3	30.7	25.9	3.6	27.1	0.00155	88.2
2014-09-20 21:40:00	0.27	15.6	103.6	26.9	21.3	5.8	21.2	0.00121	78.6
2014-10-07 16:20:00	0.13	12.4	82.4	21.4	2.2	0.3	21.1	0.00121	98.7
2014-11-24 0:00:00	0.48	19.6	130.2	35.2	24.7	11.8	23.3	0.00133	66.3
2015-04-08 10:20:00	0.32	14.8	98.3	26.5	18.9	6.0	20.5	0.00117	77.2

2015-04-09 14:50:00	0.22	16.2	107.6	29.1	45.6	10.0	19.0	0.00109	65.5
2015-04-19 22:40:00	0.2	20.0	132.9	34.5	80.7	16.1	18.4	0.00105	53.3
2015-04-21 11:50:00	0.16	7.2	47.8	12.4	16.5	2.6	9.8	0.00056	78.8
2015-05-30 12:50:00	0.46	47.8	317.5	82.6	24.4	11.2	71.3	0.00408	86.4
2015-06-27 10:40:00	0.2	54.0	358.7	93.3	135.8	27.2	66.1	0.00378	70.9
2015-07-07 12:40:00	0.44	14.6	97.0	25.2	12.3	5.4	19.8	0.00113	78.5
count	38	38	38	38	38	38	38	38	38
average	0.32	16.90	112.27	29.48	32.37	8.30	21.18	0.00121	72.72
median	0.25	14.50	96.33	25.05	19.71	4.77	18.31	0.00105	78.52
25th percentile	0.20	10.35	68.76	17.88	6.16	2.09	12.22	0.00070	63.79
75th percentile	0.37	17.80	118.25	31.09	35.06	10.93	23.31	0.00133	88.60
WQ Guideline	0.03	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Table D-5: Water Quality Performance for Total Phosphorus (TP) for LV-4

Starting Date and Time	Effluent EMC (mg/L)	Precipitation Depth (mm)	Total Estimated Influent Volume (m^3)	Total Estimated Influent Load (g)	Total Measured Effluent Volume (m^3)	Total Measured Effluent Load (g)	Estimated Pollutant Load Reduction		
							(g)	Normalized (g/m^2)	(%)
2013-06-10 7:50:00	0.35	33.0	51428.9	13.4	1475.4	0.5	12.9	0.0031	96.1
2013-07-08 16:10:00	0.76	81.6	127169.5	33.1	151521.0	115.2	-82.1	-0.0199	-248.3
2014-04-29 7:20:00	0.52	41.4	64519.8	16.8	14636.4	7.6	9.2	0.0022	54.6
2014-07-27 18:50:00	0.19	33.6	52363.9	13.6	5895.6	1.1	12.5	0.0030	91.8
2014-09-05 19:00:00	0.18	34.0	52987.3	13.8	15179.4	2.7	11.0	0.0027	80.2
2015-06-27 10:40:00	0.32	54.0	84156.3	21.9	19193.4	6.1	15.7	0.0038	71.9
count	6	6	6	6	6	6	6	6	6
average	0.39	46.27	72104.29	18.75	34650.20	22.21	-3.47	-0.0008	24.39
median	0.34	37.70	58753.57	15.28	14907.90	4.44	11.77	0.0029	76.05
25th percentile	0.22	33.70	52519.77	13.66	8080.80	1.52	9.63	0.0023	58.95
75th percentile	0.48	50.85	79247.18	20.60	18189.90	7.24	12.76	0.0031	88.87
WQ Guideline	0.03	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Table D-6: Water Quality Performance for Phosphate (PO_4) for LV-2

Starting Date and Time	Effluent EMC (mg/L)	Precipitation Depth (mm)	Total Estimated Influent Volume (m^3)	Total Estimated Influent Load (g)	Total Measured Effluent Volume (m^3)	Total Measured Effluent Load (g)	Estimated Pollutant Load Reduction		
							(g)	Normalized (g/m^2)	(%)
2013-04-08 15:20:00	0.13	10.8	71.7	7.2	11.9	1.5	5.6	0.00032	78.5
2013-04-09 15:10:00	0.15	67.8	450.4	45.0	238.3	35.7	9.3	0.00053	20.6
2013-04-24 10:30:00	0.1	14.4	95.7	13.4	30.2	3.0	10.4	0.00059	77.4
2013-04-28 17:30:00	0.1	12.2	81.0	11.3	22.6	2.3	9.1	0.00052	80.1
2013-05-10 8:50:00	0.12	22.0	146.2	20.5	62.5	7.5	13.0	0.00074	63.4
2013-05-20 21:40:00	0.12	7.2	47.8	6.7	4.9	0.6	6.1	0.00035	91.3
2013-05-31 17:00:00	0.33	4.0	26.6	3.7	6.0	2.0	1.7	0.00010	46.8
2013-06-13 9:30:00	0.15	5.2	34.5	4.8	3.0	0.5	4.4	0.00025	90.6
2013-06-16 5:10:00	0.14	10.8	71.7	10.0	22.0	3.1	7.0	0.00040	69.4
2013-07-07 0:30:00	0.14	5.6	37.2	5.2	1.0	0.1	5.1	0.00029	97.4
2013-07-19 17:10:00	0.23	12.6	83.7	11.7	4.7	1.1	10.6	0.00061	90.7
2013-08-02 15:10:00	0.15	3.6	23.9	3.3	0.0	0.0	3.3	0.00019	100.0
2013-08-26 3:40:00	0.13	15.4	102.3	14.3	3.3	0.4	13.9	0.00079	97.0
2013-08-27 17:30:00	0.13	20.2	134.2	18.8	22.0	2.9	15.9	0.00091	84.8
2013-09-20 22:00:00	0.11	34.0	225.9	31.6	2.8	0.3	31.3	0.00179	99.0
2013-10-31 3:20:00	0.15	13.6	90.3	12.6	1.1	0.2	12.5	0.00071	98.7
2014-04-04 10:10:00	0.17	9.2	61.1	6.1	6.9	1.2	4.9	0.00028	80.8
2014-04-07 17:00:00	0.18	17.4	115.6	11.6	36.7	6.6	5.0	0.00028	42.9
2014-04-12 23:20:00	0.095	7.4	49.2	4.9	6.7	0.6	4.3	0.00024	87.1
2014-05-13 3:30:00	0.17	14.6	97.0	13.6	48.5	8.3	5.3	0.00030	39.2
2014-05-13 19:00:00	0.11	4.0	26.6	3.7	20.5	2.3	1.5	0.00008	39.3
2014-05-14 17:00:00	0.17	10.2	67.8	9.5	65.9	11.2	-1.7	-0.00010	-18.2
2014-05-15 10:30:00	0.11	17.8	118.3	16.6	115.5	12.7	3.9	0.00022	23.3
2014-06-17 17:50:00	0.22	10.8	71.7	10.0	14.8	3.3	6.8	0.00039	67.5
2014-06-25 17:40:00	0.074	16.8	111.6	15.6	14.1	1.0	14.6	0.00083	93.3
2014-08-11 22:50:00	0.27	23.4	155.5	21.8	43.1	11.6	10.1	0.00058	46.5

2014-09-02 11:30:00	0.15	11.2	74.4	10.4	12.8	1.9	8.5	0.00049	81.6
2014-09-10 15:50:00	0.085	17.8	118.3	16.6	25.9	2.2	14.4	0.00082	86.7
2014-09-20 21:40:00	0.15	15.6	103.6	14.5	21.3	3.2	11.3	0.00065	77.9
2014-10-07 16:20:00	0.16	12.4	82.4	11.5	2.2	0.3	11.2	0.00064	97.0
2014-11-24 0:00:00	0.35	19.6	130.2	13.0	24.7	8.6	4.4	0.00025	33.7
2015-04-08 10:20:00	0.18	14.8	98.3	9.8	18.9	3.4	6.4	0.00037	65.4
2015-04-09 14:50:00	0.16	16.2	107.6	10.8	45.6	7.3	3.5	0.00020	32.2
2015-04-19 22:40:00	0.13	20.0	132.9	18.6	80.7	10.5	8.1	0.00046	43.6
2015-04-21 11:50:00	0.13	7.2	47.8	6.7	16.5	2.1	4.6	0.00026	68.1
2015-05-30 12:50:00	0.24	47.8	317.5	44.5	24.4	5.9	38.6	0.00221	86.8
2015-06-27 10:40:00	0.12	54.0	358.7	50.2	135.8	16.3	33.9	0.00194	67.6
2015-07-07 12:40:00	0.25	14.6	97.0	13.6	12.3	3.1	10.5	0.00060	77.3
count	38	38	38	38	38	38	38	38	38
average	0.16	16.90	112.27	14.58	32.37	4.86	9.71	0.00055	68.56
median	0.15	14.50	96.33	11.64	19.71	2.56	7.54	0.00043	77.68
25th percentile	0.12	10.35	68.76	7.75	6.16	1.05	4.65	0.00027	46.56
75th percentile	0.17	17.80	118.25	16.32	35.06	7.12	11.28	0.00064	89.75
WQ Guideline	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Table D-6: Water Quality Performance for Phosphate (PO_4) for LV-4

Starting Date and Time	Effluent EMC (mg/L)	Precipitation Depth (mm)	Total Estimated Influent Volume (m^3)	Total Estimated Influent Load (g)	Total Measured Effluent Volume (m^3)	Total Measured Effluent Load (g)	Estimated Pollutant Load Reduction		
							(g)	Normalized (g/m^2)	(%)
2013-06-10 7:50:00	6	6	6	6	6	6	6	0.0016	6
2013-07-08 16:10:00	0.30	46.27	72104.29	10.09	34650.20	18.80	-8.71	-0.0200	-16.78
2014-04-29 7:20:00	0.25	37.70	58753.57	8.23	14907.90	3.02	5.99	0.0009	69.80
2014-07-27 18:50:00	0.18	33.70	52519.77	7.35	8080.80	1.16	4.11	0.0016	46.08
2014-09-05 19:00:00	0.35	50.85	79247.18	11.09	18189.90	5.12	6.69	0.0014	84.21
2015-06-27 10:40:00	6	6	6	6	6	6	6	0.0018	6
count	0.30	46.27	72104.29	10.09	34650.20	18.80	-8.71	6	-16.78
average	0.25	37.70	58753.57	8.23	14907.90	3.02	5.99	-0.0021	69.80
median	0.18	33.70	52519.77	7.35	8080.80	1.16	4.11	0.0015	46.08

25th percentile	0.35	50.85	79247.18	11.09	18189.90	5.12	6.69	0.0010	84.21
75th percentile	6	6	6	6	6	6	6	0.0016	6
WQ Guideline	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Table D-7: Water Quality Performance for Nitrite + Nitrate (NO_2 + NO_3) for LV-2

Starting Date and Time	Effluent EMC (mg/L)	Precipitation Depth (mm)	Total Estimated Influent Volume (m^3)	Total Estimated Influent Load (g)	Total Measured Effluent Volume (m^3)	Total Measured Effluent Load (g)	Estimated Pollutant Load Reduction		
							(g)	Normalized (g/m^2)	(%)
2013-04-08 15:20:00	1.2	10.8	71.7	43.0	11.9	14.2	28.8	0.00165	66.9
2013-04-09 15:10:00	1.5	67.8	450.4	270.2	238.3	357.4	-87.2	-0.00498	-32.3
2013-04-24 10:30:00	0.47	14.4	95.7	27.7	30.2	14.2	13.5	0.00077	48.8
2013-04-28 17:30:00	0.36	12.2	81.0	23.5	22.6	8.1	15.4	0.00088	65.4
2013-05-10 8:50:00	0.74	22.0	146.2	42.4	62.5	46.2	-3.9	-0.00022	-9.1
2013-05-20 21:40:00	0.79	7.2	47.8	13.9	4.9	3.8	10.0	0.00057	72.3
2013-05-31 17:00:00	0.23	4.0	26.6	7.7	6.0	1.4	6.3	0.00036	82.1
2013-06-13 9:30:00	0.69	5.2	34.5	10.0	3.0	2.1	7.9	0.00045	79.2
2013-06-16 5:10:00	0.37	10.8	71.7	20.8	22.0	8.1	12.7	0.00072	61.0
2013-07-07 0:30:00	0.3	5.6	37.2	10.8	1.0	0.3	10.5	0.00060	97.3
2013-07-19 17:10:00	1.6	12.6	83.7	24.3	4.7	7.6	16.7	0.00095	68.8
2013-08-02 15:10:00	0.57	3.6	23.9	6.9	0.0	0.0	6.9	0.00040	100.0
2013-08-26 3:40:00	0.55	15.4	102.3	29.7	3.3	1.8	27.8	0.00159	93.8
2013-08-27 17:30:00	0.8	20.2	134.2	38.9	22.0	17.6	21.3	0.00122	54.8
2013-09-20 22:00:00	0.52	34.0	225.9	65.5	2.8	1.4	64.1	0.00366	97.8
2013-10-31 3:20:00	0.37	13.6	90.3	26.2	1.1	0.4	25.8	0.00147	98.4
2014-04-04 10:10:00	2.29	9.2	61.1	36.7	6.9	15.8	20.9	0.00119	57.0
2014-04-07 17:00:00	2.13	17.4	115.6	69.4	36.7	78.1	-8.8	-0.00050	-12.6
2014-04-12 23:20:00	2.46	7.4	49.2	29.5	6.7	16.4	13.1	0.00075	44.4
2014-05-13 3:30:00	0.59	14.6	97.0	28.1	48.5	28.6	-0.5	-0.00003	-1.8
2014-05-13 19:00:00	0.59	4.0	26.6	7.7	20.5	12.1	-4.4	-0.00025	-57.2
2014-05-14 17:00:00	0.45	10.2	67.8	19.7	65.9	29.7	-10.0	-0.00057	-51.0

2014-05-15 10:30:00	0.91	17.8	118.3	34.3	115.5	105.1	-70.8	-0.00404	-206.5
2014-06-17 17:50:00	0.39	10.8	71.7	20.8	14.8	5.8	15.0	0.00086	72.2
2014-06-25 17:40:00	0.46	16.8	111.6	32.4	14.1	6.5	25.9	0.00148	80.0
2014-08-11 22:50:00	0.32	23.4	155.5	45.1	43.1	13.8	31.3	0.00179	69.4
2014-09-02 11:30:00	0.65	11.2	74.4	21.6	12.8	8.3	13.3	0.00076	61.5
2014-09-10 15:50:00	0.43	17.8	118.3	34.3	25.9	11.1	23.2	0.00132	67.5
2014-09-20 21:40:00	0.48	15.6	103.6	30.1	21.3	10.2	19.8	0.00113	65.9
2014-10-07 16:20:00	0.33	12.4	82.4	23.9	2.2	0.7	23.2	0.00132	97.0
2014-11-24 0:00:00	0.32	19.6	130.2	78.1	24.7	7.9	70.2	0.00401	89.9
2015-04-08 10:20:00	1.38	14.8	98.3	59.0	18.9	26.1	32.9	0.00188	55.8
2015-04-09 14:50:00	1.92	16.2	107.6	64.6	45.6	87.5	-23.0	-0.00131	-35.6
2015-04-19 22:40:00	1.18	20.0	132.9	38.5	80.7	95.3	-56.7	-0.00324	-147.2
2015-04-21 11:50:00	1.53	7.2	47.8	13.9	16.5	25.2	-11.3	-0.00065	-81.5
2015-05-30 12:50:00	0.48	47.8	317.5	92.1	24.4	11.7	80.4	0.00459	87.3
2015-06-27 10:40:00	0.36	54.0	358.7	104.0	135.8	48.9	55.1	0.00315	53.0
2015-07-07 12:40:00	0.57	14.6	97.0	28.1	12.3	7.0	21.1	0.00121	75.0
count	38	38	38	38	38	38	38	38	38
average	0.82	16.90	112.27	41.40	32.37	29.91	11.49	0.00066	37.57
median	0.57	14.50	96.33	29.58	19.71	11.43	14.28	0.00082	65.65
25th percentile	0.40	10.35	68.76	21.00	6.16	5.96	1.20	0.00007	9.75
75th percentile	1.11	17.80	118.25	42.88	35.06	25.84	25.13	0.00144	79.77
WQ Guideline	3[a]	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

[a]Water quality guideline for Nitrate used

Table D-7: Water Quality Performance for Nitrite + Nitrate (NO_2 + NO_3) for LV-4

Starting Date and Time	Effluent EMC (mg/L)	Precipitation Depth (mm)	Total Estimated Influent Volume (m^3)	Total Estimated Influent Load (g)	Total Measured Effluent Volume (m^3)	Total Measured Effluent Load (g)	Estimated Pollutant Load Reduction		
							(g)	Normalized (g/m^2)	(%)
2013-06-10 7:50:00	1.2	33.0	51428.9	14.9	1475.4	1.8	13.1	0.0032	88.1
2013-07-08 16:10:00	1.1	81.6	127169.5	36.9	151521.0	166.7	-129.8	-0.0315	-351.9
2014-04-29 7:20:00	5.01	41.4	64519.8	18.7	14636.4	73.3	-54.6	-0.0133	-291.9

2014-07-27 18:50:00	1.88	33.6	52363.9	15.2	5895.6	11.1	4.1	0.0010	27.0
2014-09-05 19:00:00	2.64	34.0	52987.3	15.4	15179.4	40.1	-24.7	-0.0060	-160.8
2015-06-27 10:40:00	1.69	54.0	84156.3	24.4	19193.4	32.4	-8.0	-0.0019	-32.9
count	6	6	6	6	6	6	6	6	6
average	2.25	46.27	72104.29	20.91	34650.20	54.23	-33.32	-0.0081	-120.40
median	1.79	37.70	58753.57	17.04	14907.90	36.26	-16.37	-0.0040	-96.85
25th percentile	1.32	33.70	52519.77	15.23	8080.80	16.42	-47.14	-0.0114	-259.13
75th percentile	2.45	50.85	79247.18	22.98	18189.90	65.01	1.07	0.0003	12.03
WQ Guideline	3[a]	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

[a]Water quality guideline for Nitrate used

Table D-8: Water Quality Performance for Total Kjeldahl Nitrogen (TKN) for LV-2

Starting Date and Time	Effluent EMC (mg/L)	Precipitation Depth (mm)	Total Estimated Influent Volume (m^3)	Total Estimated Influent Load (g)	Total Measured Effluent Volume (m^3)	Total Measured Effluent Load (g)	Estimated Pollutant Load Reduction		
							(g)	Normalized (g/m^2)	(%)
2013-04-08 15:20:00	4.7	10.8	71.7	111.2	11.9	55.8	55.4	0.00317	49.8
2013-04-09 15:10:00	1.5	67.8	450.4	698.1	238.3	357.4	340.7	0.01947	48.8
2013-04-24 10:30:00	1.3	14.4	95.7	119.6	30.2	39.3	80.3	0.00459	67.1
2013-04-28 17:30:00	1	12.2	81.0	101.3	22.6	22.6	78.7	0.00450	77.7
2013-05-10 8:50:00	2.7	22.0	146.2	182.7	62.5	168.7	14.0	0.00080	7.7
2013-05-20 21:40:00	4.1	7.2	47.8	59.8	4.9	19.9	39.9	0.00228	66.7
2013-05-31 17:00:00	2.5	4.0	26.6	33.2	6.0	15.0	18.2	0.00104	54.9
2013-06-13 9:30:00	1.9	5.2	34.5	43.2	3.0	5.7	37.4	0.00214	86.7
2013-06-16 5:10:00	1.2	10.8	71.7	89.7	22.0	26.3	63.3	0.00362	70.6
2013-07-07 0:30:00	4.2	5.6	37.2	46.5	1.0	4.1	42.5	0.00243	91.3
2013-07-19 17:10:00	2.6	12.6	83.7	104.6	4.7	12.3	92.3	0.00528	88.2
2013-08-02 15:10:00	0.55	3.6	23.9	29.9	0.0	0.0	29.9	0.00171	100.0
2013-08-26 3:40:00	3.2	15.4	102.3	127.9	3.3	10.7	117.2	0.00669	91.6
2013-08-27 17:30:00	1.2	20.2	134.2	167.7	22.0	26.4	141.4	0.00808	84.3
2013-09-20 22:00:00	1.3	34.0	225.9	282.3	2.8	3.6	278.7	0.01592	98.7
2013-10-31 3:20:00	0.84	13.6	90.3	112.9	1.1	0.9	112.0	0.00640	99.2
2014-04-04 10:10:00	1.5	9.2	61.1	94.7	6.9	10.3	84.4	0.00482	89.1

2014-04-07 17:00:00	1.3	17.4	115.6	179.2	36.7	47.7	131.5	0.00751	73.4
2014-04-12 23:20:00	2	7.4	49.2	76.2	6.7	13.3	62.9	0.00359	82.5
2014-05-13 3:30:00	3.2	14.6	97.0	121.2	48.5	155.3	-34.1	-0.00195	-28.1
2014-05-13 19:00:00	1.5	4.0	26.6	33.2	20.5	30.8	2.4	0.00014	7.3
2014-05-14 17:00:00	1.1	10.2	67.8	84.7	65.9	72.5	12.2	0.00070	14.4
2014-05-15 10:30:00	1.1	17.8	118.3	147.8	115.5	127.0	20.8	0.00119	14.1
2014-06-17 17:50:00	1.3	10.8	71.7	89.7	14.8	19.3	70.4	0.00402	78.5
2014-06-25 17:40:00	0.95	16.8	111.6	139.5	14.1	13.4	126.1	0.00721	90.4
2014-08-11 22:50:00	1.1	23.4	155.5	194.3	43.1	47.5	146.9	0.00839	75.6
2014-09-02 11:30:00	1.6	11.2	74.4	93.0	12.8	20.4	72.6	0.00415	78.0
2014-09-10 15:50:00	0.47	17.8	118.3	147.8	25.9	12.2	135.6	0.00775	91.8
2014-09-20 21:40:00	0.98	15.6	103.6	129.5	21.3	20.9	108.6	0.00621	83.9
2014-10-07 16:20:00	0.14	12.4	82.4	103.0	2.2	0.3	102.7	0.00587	99.7
2014-11-24 0:00:00	1.2	19.6	130.2	201.8	24.7	29.6	172.2	0.00984	85.3
2015-04-08 10:20:00	1.3	14.8	98.3	152.4	18.9	24.5	127.9	0.00730	83.9
2015-04-09 14:50:00	0.95	16.2	107.6	166.8	45.6	43.3	123.5	0.00706	74.0
2015-04-19 22:40:00	0.71	20.0	132.9	166.1	80.7	57.3	108.8	0.00621	65.5
2015-04-21 11:50:00	1.1	7.2	47.8	59.8	16.5	18.1	41.7	0.00238	69.7
2015-05-30 12:50:00	1.2	47.8	317.5	396.9	24.4	29.3	367.6	0.02100	92.6
2015-06-27 10:40:00	0.53	54.0	358.7	448.4	135.8	72.0	376.4	0.02151	83.9
2015-07-07 12:40:00	0.93	14.6	97.0	121.2	12.3	11.5	109.8	0.00627	90.5
count	38	38	38	38	38	38	38	38	38
average	1.60	16.90	112.27	148.90	32.37	43.30	105.60	0.00603	70.51
median	1.25	14.50	96.33	120.41	19.71	21.76	88.37	0.00505	80.50
25th percentile	0.99	10.35	68.76	89.68	6.16	12.20	41.88	0.00239	66.78
75th percentile	1.83	17.80	118.25	166.63	35.06	46.42	127.42	0.00728	90.07
WQ Guideline	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Table D-8: Water Quality Performance for Total Kjeldahl Nitrogen (TKN) for LV-4

Starting Date and Time	Effluent EMC (mg/L)	Precipitation Depth (mm)	Total Estimated Influent Volume (m^3)	Total Estimated Influent Load (g)	Total Measured Effluent Volume (m^3)	Total Measured Effluent Load (g)	Estimated Pollutant Load Reduction		
							(g)	Normalized (g/m^2)	(%)
2013-06-10 7:50:00	1.4	33.0	51428.9	64.3	1475.4	2.1	62.2	0.0151	96.8
2013-07-08 16:10:00	2.9	81.6	127169.5	159.0	151521.0	439.4	-280.4	-0.0681	-176.4
2014-04-29 7:20:00	2	41.4	64519.8	80.6	14636.4	29.3	51.4	0.0125	63.7
2014-07-27 18:50:00		33.6	52363.9	65.5	5895.6	5.9	59.6	0.0145	91.0
2014-09-05 19:00:00	1.7	34.0	52987.3	66.2	15179.4	25.8	40.4	0.0098	61.0
2015-06-27 10:40:00	0.82	54.0	84156.3	105.2	19193.4	15.7	89.5	0.0217	85.0
count	5	6	6	6	6	6	6	6	6
average	1.76	46.27	72104.29	90.13	34650.20	86.36	3.77	0.0009	36.86
median	1.70	37.70	58753.57	73.44	14907.90	20.77	55.47	0.0135	74.37
25th percentile	1.40	33.70	52519.77	65.65	8080.80	8.36	43.17	0.0105	61.71
75th percentile	2.00	50.85	79247.18	99.06	18189.90	28.41	61.56	0.0149	89.50
WQ Guideline	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Table D-9: Water Quality Performance for Cadmium (Cd) for LV-2

Starting Date and Time	Effluent EMC (mg/L)	Precipitation Depth (mm)	Total Estimated Influent Volume (m^3)	Total Estimated Influent Load (g)	Total Measured Effluent Volume (m^3)	Total Measured Effluent Load (g)	Estimated Pollutant Load Reduction		
							(g)	Normalized (g/m^2)	(%)
2013-04-08 15:20:00	0.43	10.8	71.7	0.01865	11.9	0.00511	0.0	0.00000	72.6
2013-04-09 15:10:00	0.23	67.8	450.4	0.11711	238.3	0.05481	0.1	0.00000	53.2
2013-04-24 10:30:00	0.2	14.4	95.7	0.01626	30.2	0.00605	0.0	0.00000	62.8
2013-04-28 17:30:00	0.09	12.2	81.0	0.01378	22.6	0.00203	0.0	0.00000	85.2
2013-05-10 8:50:00	0.17	22.0	146.2	0.02485	62.5	0.01062	0.0	0.00000	57.3
2013-05-20 21:40:00	0.52	7.2	47.8	0.00813	4.9	0.00253	0.0	0.00000	68.9
2013-05-31 17:00:00	0.16	4.0	26.6	0.00452	6.0	0.00096	0.0	0.00000	78.8
2013-06-13 9:30:00	0.14	5.2	34.5	0.00587	3.0	0.00042	0.0	0.00000	92.8
2013-06-16 5:10:00	0.26	10.8	71.7	0.01220	22.0	0.00571	0.0	0.00000	53.2
2013-07-07 0:30:00	0.86	5.6	37.2	0.00632	1.0	0.00083	0.0	0.00000	86.9

2013-07-19 17:10:00	0.23	12.6	83.7	0.01423	4.7	0.00109	0.0	0.00000	92.4
2013-08-02 15:10:00	0.1	3.6	23.9	0.00407	0.0	0.00000	0.0	0.00000	100.0
2013-08-26 3:40:00	0.16	15.4	102.3	0.01739	3.3	0.00054	0.0	0.00000	96.9
2013-08-27 17:30:00	0.12	20.2	134.2	0.02281	22.0	0.00264	0.0	0.00000	88.4
2013-09-20 22:00:00	0.13	34.0	225.9	0.03840	2.8	0.00036	0.0	0.00000	99.1
2013-10-31 3:20:00	0.09	13.6	90.3	0.01536	1.1	0.00010	0.0	0.00000	99.3
2014-04-04 10:10:00	0.18	9.2	61.1	0.01589	6.9	0.00124	0.0	0.00000	92.2
2014-04-07 17:00:00	0.18	17.4	115.6	0.03005	36.7	0.00660	0.0	0.00000	78.0
2014-04-12 23:20:00	0.17	7.4	49.2	0.01278	6.7	0.00113	0.0	0.00000	91.1
2014-05-13 3:30:00	0.1	14.6	97.0	0.01649	48.5	0.00485	0.0	0.00000	70.6
2014-05-13 19:00:00	0.11	4.0	26.6	0.00452	20.5	0.00226	0.0	0.00000	50.0
2014-05-14 17:00:00	0.2	10.2	67.8	0.01152	65.9	0.01319	0.0	0.00000	-14.5
2014-05-15 10:30:00	0.12	17.8	118.3	0.02010	115.5	0.01386	0.0	0.00000	31.1
2014-06-17 17:50:00	0.18	10.8	71.7	0.01220	14.8	0.00267	0.0	0.00000	78.1
2014-06-25 17:40:00	0.08	16.8	111.6	0.01897	14.1	0.00113	0.0	0.00000	94.1
2014-08-11 22:50:00	0.2	23.4	155.5	0.02643	43.1	0.00863	0.0	0.00000	67.3
2014-09-02 11:30:00	0.18	11.2	74.4	0.01265	12.8	0.00230	0.0	0.00000	81.8
2014-09-10 15:50:00	0.36	17.8	118.3	0.02010	25.9	0.00932	0.0	0.00000	53.6
2014-09-20 21:40:00	0.21	15.6	103.6	0.01762	21.3	0.00448	0.0	0.00000	74.6
2014-10-07 16:20:00	0.06	12.4	82.4	0.01400	2.2	0.00013	0.0	0.00000	99.1
2014-11-24 0:00:00	0.13	19.6	130.2	0.03385	24.7	0.00321	0.0	0.00000	90.5
2015-04-08 10:20:00	0.39	14.8	98.3	0.02556	18.9	0.00736	0.0	0.00000	71.2
2015-04-09 14:50:00	0.19	16.2	107.6	0.02798	45.6	0.00866	0.0	0.00000	69.0
2015-04-19 22:40:00	0.15	20.0	132.9	0.02259	80.7	0.01211	0.0	0.00000	46.4
2015-04-21 11:50:00	0.14	7.2	47.8	0.00813	16.5	0.00230	0.0	0.00000	71.7
2015-05-30 12:50:00	0.14	47.8	317.5	0.05398	24.4	0.00342	0.1	0.00000	93.7
2015-06-27 10:40:00	0.16	54.0	358.7	0.06099	135.8	0.02173	0.0	0.00000	64.4
2015-07-07 12:40:00	0.16	14.6	97.0	0.01649	12.3	0.00197	0.0	0.00000	88.0
count	38	38	38	38	38	38	38	38	38
average	0.20	16.90	112.27	0.02	32.37	0.01	0.02	0.00	74.47
median	0.17	14.50	96.33	0.02	19.71	0.00	0.01	0.00	78.07

25th percentile	0.13	10.35	68.76	0.01	6.16	0.00	0.01	0.00	65.12
75th percentile	0.20	17.80	118.25	0.02	35.06	0.01	0.02	0.00	91.93
WQ Guideline	0.2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Table D-9: Water Quality Performance for Cadmium (Cd) for LV-4

Starting Date and Time	Effluent EMC (µg/L)	Precipitation Depth (mm)	Total Estimated Influent Volume (m^3)	Total Estimated Influent Load (g)	Total Measured Effluent Volume (m^3)	Total Measured Effluent Load (g)	Estimated Pollutant Load Reduction		
							(g)	Normalized (g/m^2)	(%)
2013-06-10 7:50:00	0.12	33.0	51428.9	0.00874	1475.4	0.00018	0.0085659	0.0000021	98.0
2013-07-08 16:10:00	0.33	81.6	127169.5	0.02162	151521.0	0.05000	-0.0283831	-0.0000069	-131.3
2014-04-29 7:20:00	0.14	41.4	64519.8	0.01097	14636.4	0.00205	0.0089193	0.0000022	81.3
2014-07-27 18:50:00	0.15	33.6	52363.9	0.00890	5895.6	0.00088	0.0080175	0.0000019	90.1
2014-09-05 19:00:00	0.1	34.0	52987.3	0.00901	15179.4	0.00152	0.0074899	0.0000018	83.1
2015-06-27 10:40:00	0.1	54.0	84156.3	0.01431	19193.4	0.00192	0.0123872	0.0000030	86.6
count	6	6	6	6	6	6	6	6	6
average	0.16	46.27	72104.29	0.01	34650.20	0.01	0.00	0.0000007	51.30
median	0.13	37.70	58753.57	0.01	14907.90	0.00	0.01	0.0000020	84.87
25th percentile	0.11	33.70	52519.77	0.01	8080.80	0.00	0.01	0.0000018	81.78
75th percentile	0.15	50.85	79247.18	0.01	18189.90	0.00	0.01	0.0000021	89.20
WQ Guideline	0.2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Table D-10: Water Quality Performance for Copper (Cu) for LV-2

Starting Date and Time	Effluent EMC (mg/L)	Precipitation Depth (mm)	Total Estimated Influent Volume (m^3)	Total Estimated Influent Load (g)	Total Measured Effluent Volume (m^3)	Total Measured Effluent Load (g)	Estimated Pollutant Load Reduction		
							(g)	Normalized (g/m^2)	(%)
2013-04-08 15:20:00	27.1	10.8	71.7	1.31298	11.9	0.32180	0.9912	0.00006	75.5
2013-04-09 15:10:00	18.9	67.8	450.4	8.24261	238.3	4.50379	3.7388	0.00021	45.4
2013-04-24 10:30:00	16.8	14.4	95.7	1.42539	30.2	0.50794	0.9174	0.00005	64.4
2013-04-28 17:30:00	11.4	12.2	81.0	1.20762	22.6	0.25761	0.9500	0.00005	78.7
2013-05-10 8:50:00	17.2	22.0	146.2	2.17767	62.5	1.07464	1.1030	0.00006	50.7
2013-05-20 21:40:00	22.3	7.2	47.8	0.71269	4.9	0.10843	0.6043	0.00003	84.8

2013-05-31 17:00:00	18.7	4.0	26.6	0.39594	6.0	0.11212	0.2838	0.00002	71.7
2013-06-13 9:30:00	13.2	5.2	34.5	0.51472	3.0	0.03989	0.4748	0.00003	92.3
2013-06-16 5:10:00	11.9	10.8	71.7	1.06904	22.0	0.26127	0.8078	0.00005	75.6
2013-07-07 0:30:00	40.7	5.6	37.2	0.55432	1.0	0.03927	0.5150	0.00003	92.9
2013-07-19 17:10:00	23.3	12.6	83.7	1.24721	4.7	0.11022	1.1370	0.00006	91.2
2013-08-02 15:10:00	9.1	3.6	23.9	0.35635	0.0	0.00000	0.3563	0.00002	100.0
2013-08-26 3:40:00	21.7	15.4	102.3	1.52437	3.3	0.07261	1.4518	0.00008	95.2
2013-08-27 17:30:00	13.7	20.2	134.2	1.99950	22.0	0.30125	1.6983	0.00010	84.9
2013-09-20 22:00:00	9.6	34.0	225.9	3.36550	2.8	0.02673	3.3388	0.00019	99.2
2013-10-31 3:20:00	16.5	13.6	90.3	1.34620	1.1	0.01860	1.3276	0.00008	98.6
2014-04-04 10:10:00	24	9.2	61.1	1.11847	6.9	0.16534	0.9531	0.00005	85.2
2014-04-07 17:00:00	19	17.4	115.6	2.11536	36.7	0.69678	1.4186	0.00008	67.1
2014-04-12 23:20:00	23	7.4	49.2	0.89964	6.7	0.15326	0.7464	0.00004	83.0
2014-05-13 3:30:00	20.2	14.6	97.0	1.44518	48.5	0.98045	0.4647	0.00003	32.2
2014-05-13 19:00:00	23.1	4.0	26.6	0.39594	20.5	0.47443	-0.0785	0.00000	-19.8
2014-05-14 17:00:00	16.8	10.2	67.8	1.00965	65.9	1.10780	-0.0982	-0.00001	-9.7
2014-05-15 10:30:00	13.5	17.8	118.3	1.76194	115.5	1.55905	0.2029	0.00001	11.5
2014-06-17 17:50:00	17.7	10.8	71.7	1.06904	14.8	0.26261	0.8064	0.00005	75.4
2014-06-25 17:40:00	11.5	16.8	111.6	1.66295	14.1	0.16213	1.5008	0.00009	90.3
2014-08-11 22:50:00	14.7	23.4	155.5	2.31625	43.1	0.63420	1.6821	0.00010	72.6
2014-09-02 11:30:00	22.7	11.2	74.4	1.10863	12.8	0.29005	0.8186	0.00005	73.8
2014-09-10 15:50:00	12.3	17.8	118.3	1.76194	25.9	0.31856	1.4434	0.00008	81.9
2014-09-20 21:40:00	18.4	15.6	103.6	1.54417	21.3	0.39268	1.1515	0.00007	74.6
2014-10-07 16:20:00	8.4	12.4	82.4	1.22742	2.2	0.01834	1.2091	0.00007	98.5
2014-11-24 0:00:00	11.1	19.6	130.2	2.38282	24.7	0.27369	2.1091	0.00012	88.5
2015-04-08 10:20:00	17.9	14.8	98.3	1.79927	18.9	0.33798	1.4613	0.00008	81.2
2015-04-09 14:50:00	16.4	16.2	107.6	1.96947	45.6	0.74771	1.2218	0.00007	62.0
2015-04-19 22:40:00	17.7	20.0	132.9	1.97970	80.7	1.42900	0.5507	0.00003	27.8
2015-04-21 11:50:00	18.3	7.2	47.8	0.71269	16.5	0.30113	0.4116	0.00002	57.7
2015-05-30 12:50:00	31.8	47.8	317.5	4.73149	24.4	0.77663	3.9549	0.00023	83.6
2015-06-27 10:40:00	7.8	54.0	358.7	5.34520	135.8	1.05926	4.2859	0.00024	80.2

2015-07-07 12:40:00	18.4	14.6	97.0	1.44518	12.3	0.22677	1.2184	0.00007	84.3
count	38	38	38	38	38	38	38	38	38
average	17.81	16.90	112.27	1.77	32.37	0.53	1.24	0.00007	70.60
median	17.70	14.50	96.33	1.44	19.71	0.30	1.05	0.00006	79.43
25th percentile	13.28	10.35	68.76	1.07	6.16	0.12	0.56	0.00003	65.04
75th percentile	21.33	17.80	118.25	1.98	35.06	0.68	1.45	0.00008	87.69
WQ Guideline	5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Table D-10: Water Quality Performance for Copper (Cu) for LV-4

Starting Date and Time	Effluent EMC (µg/L)	Precipitation Depth (mm)	Total Estimated Influent Volume (m^3)	Total Estimated Influent Load (g)	Total Measured Effluent Volume (m^3)	Total Measured Effluent Load (g)	Estimated Pollutant Load Reduction		
							(g)	Normalized (g/m^2)	(%)
2013-06-10 7:50:00	16.4	33.0	51428.9	0.76629	1475.4	0.02420	0.7420933	0.0001801	96.8
2013-07-08 16:10:00	26.2	81.6	127169.5	1.89483	151521.0	3.96985	-2.0750244	-0.0005036	-109.5
2014-04-29 7:20:00	13.5	41.4	64519.8	0.96135	14636.4	0.19759	0.7637541	0.0001854	79.4
2014-07-27 18:50:00	14.1	33.6	52363.9	0.78022	5895.6	0.08313	0.6970945	0.0001692	89.3
2014-09-05 19:00:00	14.3	34.0	52987.3	0.78951	15179.4	0.21707	0.5724454	0.0001389	72.5
2015-06-27 10:40:00	12.8	54.0	84156.3	1.25393	19193.4	0.24568	1.0082534	0.0002447	80.4
count	6	6	6	6	6	6	6	6	6
average	16.22	46.27	72104.29	1.07	34650.20	0.79	0.28	0.000069	51.51
median	14.20	37.70	58753.57	0.88	14907.90	0.21	0.72	0.000175	79.93
25th percentile	13.65	33.70	52519.77	0.78	8080.80	0.11	0.60	0.000147	74.24
75th percentile	15.88	50.85	79247.18	1.18	18189.90	0.24	0.76	0.000184	87.11
WQ Guideline	5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Table D-11: Water Quality Performance for Iron (Fe) for LV-2

Starting Date and Time	Effluent EMC (mg/L)	Precipitation Depth (mm)	Total Estimated Influent Volume (m^3)	Total Estimated Influent Load (g)	Total Measured Effluent Volume (m^3)	Total Measured Effluent Load (g)	Estimated Pollutant Load Reduction		
							(g)	Normalized (g/m^2)	(%)
2013-04-08 15:20:00	1160	10.8	71.7	84.30348	11.9	13.77454	70.5289	0.00403	83.7
2013-04-09 15:10:00	586	67.8	450.4	529.23849	238.3	139.64128	389.5972	0.02226	73.6
2013-04-24 10:30:00	437	14.4	95.7	45.58367	30.2	13.21252	32.3711	0.00185	71.0

2013-04-28 17:30:00	257	12.2	81.0	38.61950	22.6	5.80748	32.8120	0.00187	85.0
2013-05-10 8:50:00	588	22.0	146.2	69.64171	62.5	36.73777	32.9039	0.00188	47.2
2013-05-20 21:40:00	751	7.2	47.8	22.79183	4.9	3.65166	19.1402	0.00109	84.0
2013-05-31 17:00:00	1110	4.0	26.6	12.66213	6.0	6.65534	6.0068	0.00034	47.4
2013-06-13 9:30:00	299	5.2	34.5	16.46077	3.0	0.90346	15.5573	0.00089	94.5
2013-06-16 5:10:00	396	10.8	71.7	34.18775	22.0	8.69426	25.4935	0.00146	74.6
2013-07-07 0:30:00	5200	5.6	37.2	17.72698	1.0	5.01696	12.7100	0.00073	71.7
2013-07-19 17:10:00	381	12.6	83.7	39.88571	4.7	1.80228	38.0834	0.00218	95.5
2013-08-02 15:10:00	139	3.6	23.9	11.39592	0.0	0.00000	11.3959	0.00065	100.0
2013-08-26 3:40:00	1010	15.4	102.3	48.74920	3.3	3.37966	45.3695	0.00259	93.1
2013-08-27 17:30:00	120	20.2	134.2	63.94376	22.0	2.63866	61.3051	0.00350	95.9
2013-09-20 22:00:00	241	34.0	225.9	107.62810	2.8	0.67109	106.9570	0.00611	99.4
2013-10-31 3:20:00	216	13.6	90.3	43.05124	1.1	0.24352	42.8077	0.00245	99.4
2014-04-04 10:10:00	2200	9.2	61.1	71.81407	6.9	15.15624	56.6578	0.00324	78.9
2014-04-07 17:00:00	2000	17.4	115.6	135.82227	36.7	73.34520	62.4771	0.00357	46.0
2014-04-12 23:20:00	1100	7.4	49.2	57.76349	6.7	7.32996	50.4335	0.00288	87.3
2014-05-13 3:30:00	890	14.6	97.0	46.21677	48.5	43.19793	3.0188	0.00017	6.5
2014-05-13 19:00:00	497	4.0	26.6	12.66213	20.5	10.20739	2.4547	0.00014	19.4
2014-05-14 17:00:00	457	10.2	67.8	32.28843	65.9	30.13485	2.1536	0.00012	6.7
2014-05-15 10:30:00	295	17.8	118.3	56.34648	115.5	34.06808	22.2784	0.00127	39.5
2014-06-17 17:50:00	373	10.8	71.7	34.18775	14.8	5.53413	28.6536	0.00164	83.8
2014-06-25 17:40:00	191	16.8	111.6	53.18095	14.1	2.69276	50.4882	0.00288	94.9
2014-08-11 22:50:00	209	23.4	155.5	74.07346	43.1	9.01689	65.0566	0.00372	87.8
2014-09-02 11:30:00	441	11.2	74.4	35.45396	12.8	5.63492	29.8190	0.00170	84.1
2014-09-10 15:50:00	174	17.8	118.3	56.34648	25.9	4.50643	51.8401	0.00296	92.0
2014-09-20 21:40:00	118	15.6	103.6	49.38231	21.3	2.51829	46.8640	0.00268	94.9
2014-10-07 16:20:00	243	12.4	82.4	39.25260	2.2	0.53042	38.7222	0.00221	98.6
2014-11-24 0:00:00	488	19.6	130.2	152.99520	24.7	12.03232	140.9629	0.00805	92.1
2015-04-08 10:20:00	611	14.8	98.3	115.52699	18.9	11.53654	103.9905	0.00594	90.0
2015-04-09 14:50:00	416	16.2	107.6	126.45522	45.6	18.96636	107.4889	0.00614	85.0
2015-04-19 22:40:00	287	20.0	132.9	63.31065	80.7	23.17072	40.1399	0.00229	63.4

2015-04-21 11:50:00	483	7.2	47.8	22.79183	16.5	7.94777	14.8441	0.00085	65.1
2015-05-30 12:50:00	501	47.8	317.5	151.31245	24.4	12.23562	139.0768	0.00795	91.9
2015-06-27 10:40:00	136	54.0	358.7	170.93875	135.8	18.46910	152.4697	0.00871	89.2
2015-07-07 12:40:00	487	14.6	97.0	46.21677	12.3	6.00208	40.2147	0.00230	87.0
count	38	38	38	38	38	38	38	38	38
average	670.74	16.90	112.27	73.43	32.37	15.71	57.71	0.00330	76.32
median	439.00	14.50	96.33	49.07	19.71	7.64	40.18	0.00230	84.98
25th percentile	246.50	10.35	68.76	34.50	6.16	3.45	23.08	0.00132	71.19
75th percentile	605.25	17.80	118.25	73.51	35.06	14.81	62.18	0.00355	92.83
WQ Guideline	300	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Table D-11: Water Quality Performance for Iron (Fe) for LV-4

Starting Date and Time	Effluent EMC (µg/L)	Precipitation Depth (mm)	Total Estimated Influent Volume (m^3)	Total Estimated Influent Load (g)	Total Measured Effluent Volume (m^3)	Total Measured Effluent Load (g)	Estimated Pollutant Load Reduction		
							(g)	Normalized (g/m^2)	(%)
2013-06-10 7:50:00	300	33.0	51428.9	24.50585	1475.4	0.44262	24.0632270	0.0058406	98.2
2013-07-08 16:10:00	556	81.6	127169.5	60.59628	151521.0	84.24568	-23.6493997	-0.0057401	-39.0
2014-04-29 7:20:00	659	41.4	64519.8	30.74370	14636.4	9.64539	21.0983114	0.0051209	68.6
2014-07-27 18:50:00	223	33.6	52363.9	24.95141	5895.6	1.31472	23.6366894	0.0057371	94.7
2014-09-05 19:00:00	168	34.0	52987.3	25.24845	15179.4	2.55014	22.6983094	0.0055093	89.9
2015-06-27 10:40:00	320	54.0	84156.3	40.10048	19193.4	6.14189	33.9585895	0.0082424	84.7
count	6	6	6	6	6	6	6	6	6
average	371.00	46.27	72104.29	34.36	34650.20	17.39	16.97	0.004118	66.18
median	310.00	37.70	58753.57	28.00	14907.90	4.35	23.17	0.005623	87.29
25th percentile	242.25	33.70	52519.77	25.03	8080.80	1.62	21.50	0.005218	72.64
75th percentile	497.00	50.85	79247.18	37.76	18189.90	8.77	23.96	0.005815	93.52
WQ Guideline	300	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Table D-12: Water Quality Performance for Lead (Pb) for LV-2

Starting Date and Time	Effluent EMC (mg/L)	Precipitation Depth (mm)	Total Estimated Influent Volume (m^3)	Total Estimated Influent Load (g)	Total Measured Effluent Volume (m^3)	Total Measured Effluent Load (g)	Estimated Pollutant Load Reduction		
							(g)	Normalized (g/m^2)	(%)
2013-04-08 15:20:00	30.9	10.8	71.7	1.07621	11.9	0.36693	0.7093	0.00004	65.9
2013-04-09 15:10:00	10.8	67.8	450.4	6.75624	238.3	2.57359	4.1826	0.00024	61.9
2013-04-24 10:30:00	4.92	14.4	95.7	0.39413	30.2	0.14875	0.2454	0.00001	62.3
2013-04-28 17:30:00	2.94	12.2	81.0	0.33392	22.6	0.06644	0.2675	0.00002	80.1
2013-05-10 8:50:00	7.68	22.0	146.2	0.60215	62.5	0.47984	0.1223	0.00001	20.3
2013-05-20 21:40:00	10.8	7.2	47.8	0.19707	4.9	0.05251	0.1446	0.00001	73.4
2013-05-31 17:00:00	10.2	4.0	26.6	0.10948	6.0	0.06116	0.0483	0.00000	44.1
2013-06-13 9:30:00	2.93	5.2	34.5	0.14233	3.0	0.00885	0.1335	0.00001	93.8
2013-06-16 5:10:00	5.42	10.8	71.7	0.29560	22.0	0.11900	0.1766	0.00001	59.7
2013-07-07 0:30:00	59.8	5.6	37.2	0.15327	1.0	0.05770	0.0956	0.00001	62.4
2013-07-19 17:10:00	7.85	12.6	83.7	0.34487	4.7	0.03713	0.3077	0.00002	89.2
2013-08-02 15:10:00	1.62	3.6	23.9	0.09853	0.0	0.00000	0.0985	0.00001	100.0
2013-08-26 3:40:00	15.1	15.4	102.3	0.42150	3.3	0.05053	0.3710	0.00002	88.0
2013-08-27 17:30:00	1.58	20.2	134.2	0.55288	22.0	0.03474	0.5181	0.00003	93.7
2013-09-20 22:00:00	3.86	34.0	225.9	0.93059	2.8	0.01075	0.9198	0.00005	98.8
2013-10-31 3:20:00	2.78	13.6	90.3	0.37224	1.1	0.00313	0.3691	0.00002	99.2
2014-04-04 10:10:00	11	9.2	61.1	0.91678	6.9	0.07578	0.8410	0.00005	91.7
2014-04-07 17:00:00	10	17.4	115.6	1.73390	36.7	0.36673	1.3672	0.00008	78.8
2014-04-12 23:20:00	9.9	7.4	49.2	0.73741	6.7	0.06597	0.6714	0.00004	91.1
2014-05-13 3:30:00	10.7	14.6	97.0	0.39961	48.5	0.51935	-0.1197	-0.00001	-30.0
2014-05-13 19:00:00	6.11	4.0	26.6	0.10948	20.5	0.12549	-0.0160	0.00000	-14.6
2014-05-14 17:00:00	4.92	10.2	67.8	0.27918	65.9	0.32443	-0.0452	0.00000	-16.2
2014-05-15 10:30:00	2.5	17.8	118.3	0.48719	115.5	0.28871	0.1985	0.00001	40.7
2014-06-17 17:50:00	4.9	10.8	71.7	0.29560	14.8	0.07270	0.2229	0.00001	75.4
2014-06-25 17:40:00	1.78	16.8	111.6	0.45982	14.1	0.02509	0.4347	0.00002	94.5
2014-08-11 22:50:00	2.28	23.4	155.5	0.64047	43.1	0.09837	0.5421	0.00003	84.6

2014-09-02 11:30:00	6.28	11.2	74.4	0.30655	12.8	0.08024	0.2263	0.00001	73.8
2014-09-10 15:50:00	1.74	17.8	118.3	0.48719	25.9	0.04506	0.4421	0.00003	90.8
2014-09-20 21:40:00	2.1	15.6	103.6	0.42698	21.3	0.04482	0.3822	0.00002	89.5
2014-10-07 16:20:00	2.55	12.4	82.4	0.33939	2.2	0.00557	0.3338	0.00002	98.4
2014-11-24 0:00:00	5.75	19.6	130.2	1.95313	24.7	0.14177	1.8114	0.00010	92.7
2015-04-08 10:20:00	8.68	14.8	98.3	1.47481	18.9	0.16389	1.3109	0.00007	88.9
2015-04-09 14:50:00	6.12	16.2	107.6	1.61432	45.6	0.27902	1.3353	0.00008	82.7
2015-04-19 22:40:00	3.25	20.0	132.9	0.54741	80.7	0.26239	0.2850	0.00002	52.1
2015-04-21 11:50:00	6.15	7.2	47.8	0.19707	16.5	0.10120	0.0959	0.00001	48.6
2015-05-30 12:50:00	10.4	47.8	317.5	1.30830	24.4	0.25399	1.0543	0.00006	80.6
2015-06-27 10:40:00	1.31	54.0	358.7	1.47800	135.8	0.17790	1.3001	0.00007	88.0
2015-07-07 12:40:00	7.18	14.6	97.0	0.39961	12.3	0.08849	0.3111	0.00002	77.9
count	38	38	38	38	38	38	38	38	38
average	8.02	16.90	112.27	0.77	32.37	0.20	0.57	0.000033	69.81
median	5.93	14.50	96.33	0.42	19.71	0.08	0.32	0.000018	80.35
25th percentile	2.82	10.35	68.76	0.30	6.16	0.05	0.15	0.000009	62.00
75th percentile	9.98	17.80	118.25	0.87	35.06	0.23	0.70	0.000040	90.98
WQ Guideline	1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Table D-12: Water Quality Performance for Lead (Pb) for LV-4

Starting Date and Time	Effluent EMC (µg/L)	Precipitation Depth (mm)	Total Estimated Influent Volume (m^3)	Total Estimated Influent Load (g)	Total Measured Effluent Volume (m^3)	Total Measured Effluent Load (g)	Estimated Pollutant Load Reduction		
							(g)	Normalized (g/m^2)	(%)
2013-06-10 7:50:00	3.2	33.0	51428.9	0.21189	1475.4	0.00472	0.2071656	0.0000503	97.8
2013-07-08 16:10:00	5.2	81.6	127169.5	0.52394	151521.0	0.78791	-0.2639708	-0.0000641	-50.4
2014-04-29 7:20:00	4.6	41.4	64519.8	0.26582	14636.4	0.06733	0.1984943	0.0000482	74.7
2014-07-27 18:50:00	2.1	33.6	52363.9	0.21574	5895.6	0.01238	0.2033586	0.0000494	94.3
2014-09-05 19:00:00	1.89	34.0	52987.3	0.21831	15179.4	0.02869	0.1896186	0.0000460	86.9
2015-06-27 10:40:00	1.98	54.0	84156.3	0.34672	19193.4	0.03800	0.3087210	0.0000749	89.0
count	6	6	6	6	6	6	6	6	6
average	3.16	46.27	72104.29	0.30	34650.20	0.16	0.14	0.000034	65.37
median	2.65	37.70	58753.57	0.24	14907.90	0.03	0.20	0.000049	87.95

25th percentile	2.01	33.70	52519.77	0.22	8080.80	0.02	0.19	0.000047	77.72
75th percentile	4.25	50.85	79247.18	0.33	18189.90	0.06	0.21	0.000050	92.96
WQ Guideline	1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Table D-13: Water Quality Performance for Nickel (Ni) for LV-2

Starting Date and Time	Effluent EMC (mg/L)	Precipitation Depth (mm)	Total Estimated Influent Volume (m^3)	Total Estimated Influent Load (g)	Total Measured Effluent Volume (m^3)	Total Measured Effluent Load (g)	Estimated Pollutant Load Reduction		
							(g)	Normalized (g/m^2)	(%)
2013-04-08 15:20:00	2.6	10.8	71.7	0.23677	11.9	0.03087	0.2059	0.00001	87.0
2013-04-09 15:10:00	1.3	67.8	450.4	1.48637	238.3	0.30978	1.1766	0.00007	79.2
2013-04-24 10:30:00	0.8	14.4	95.7	0.14350	30.2	0.02419	0.1193	0.00001	83.1
2013-04-28 17:30:00	0.5	12.2	81.0	0.12157	22.6	0.01130	0.1103	0.00001	90.7
2013-05-10 8:50:00	1.3	22.0	146.2	0.21923	62.5	0.08122	0.1380	0.00001	63.0
2013-05-20 21:40:00	2	7.2	47.8	0.07175	4.9	0.00972	0.0620	0.00000	86.4
2013-05-31 17:00:00	2.2	4.0	26.6	0.03986	6.0	0.01319	0.0267	0.00000	66.9
2013-06-13 9:30:00	1.3	5.2	34.5	0.05182	3.0	0.00393	0.0479	0.00000	92.4
2013-06-16 5:10:00	1	10.8	71.7	0.10762	22.0	0.02196	0.0857	0.00000	79.6
2013-07-07 0:30:00	7.9	5.6	37.2	0.05580	1.0	0.00762	0.0482	0.00000	86.3
2013-07-19 17:10:00	2	12.6	83.7	0.12556	4.7	0.00946	0.1161	0.00001	92.5
2013-08-02 15:10:00	0.6	3.6	23.9	0.03587	0.0	0.00000	0.0359	0.00000	100.0
2013-08-26 3:40:00	2.2	15.4	102.3	0.15346	3.3	0.00736	0.1461	0.00001	95.2
2013-08-27 17:30:00	0.6	20.2	134.2	0.20129	22.0	0.01319	0.1881	0.00001	93.4
2013-09-20 22:00:00	0.6	34.0	225.9	0.33881	2.8	0.00167	0.3371	0.00002	99.5
2013-10-31 3:20:00	0.5	13.6	90.3	0.13552	1.1	0.00056	0.1350	0.00001	99.6
2014-04-04 10:10:00	3.4	9.2	61.1	0.20169	6.9	0.02342	0.1783	0.00001	88.4
2014-04-07 17:00:00	2.6	17.4	115.6	0.38146	36.7	0.09535	0.2861	0.00002	75.0
2014-04-12 23:20:00	1.9	7.4	49.2	0.16223	6.7	0.01266	0.1496	0.00001	92.2
2014-05-13 3:30:00	1.9	14.6	97.0	0.14549	48.5	0.09222	0.0533	0.00000	36.6
2014-05-13 19:00:00	1.3	4.0	26.6	0.03986	20.5	0.02670	0.0132	0.00000	33.0
2014-05-14 17:00:00	1.2	10.2	67.8	0.10164	65.9	0.07913	0.0225	0.00000	22.1

2014-05-15 10:30:00	1	17.8	118.3	0.17738	115.5	0.11549	0.0619	0.00000	34.9
2014-06-17 17:50:00	1.2	10.8	71.7	0.10762	14.8	0.01780	0.0898	0.00001	83.5
2014-06-25 17:40:00	0.8	16.8	111.6	0.16741	14.1	0.01128	0.1561	0.00001	93.3
2014-08-11 22:50:00	0.8	23.4	155.5	0.23318	43.1	0.03451	0.1987	0.00001	85.2
2014-09-02 11:30:00	1.2	11.2	74.4	0.11161	12.8	0.01533	0.0963	0.00001	86.3
2014-09-10 15:50:00	0.7	17.8	118.3	0.17738	25.9	0.01813	0.1592	0.00001	89.8
2014-09-20 21:40:00	0.6	15.6	103.6	0.15545	21.3	0.01280	0.1426	0.00001	91.8
2014-10-07 16:20:00	0.6	12.4	82.4	0.12357	2.2	0.00131	0.1223	0.00001	98.9
2014-11-24 0:00:00	1	19.6	130.2	0.42969	24.7	0.02466	0.4050	0.00002	94.3
2015-04-08 10:20:00	1.8	14.8	98.3	0.32446	18.9	0.03399	0.2905	0.00002	89.5
2015-04-09 14:50:00	1.2	16.2	107.6	0.35515	45.6	0.05471	0.3004	0.00002	84.6
2015-04-19 22:40:00	1.2	20.0	132.9	0.19930	80.7	0.09688	0.1024	0.00001	51.4
2015-04-21 11:50:00	1.6	7.2	47.8	0.07175	16.5	0.02633	0.0454	0.00000	63.3
2015-05-30 12:50:00	2	47.8	317.5	0.47632	24.4	0.04884	0.4275	0.00002	89.7
2015-06-27 10:40:00	0.8	54.0	358.7	0.53811	135.8	0.10864	0.4295	0.00002	79.8
2015-07-07 12:40:00	1.4	14.6	97.0	0.14549	12.3	0.01725	0.1282	0.00001	88.1
count	38	38	38	38	38	38	38	38	38
average	1.52	16.90	112.27	0.22	32.37	0.04	0.18	0.000010	80.17
median	1.20	14.50	96.33	0.15	19.71	0.02	0.13	0.000008	86.70
25th percentile	0.80	10.35	68.76	0.11	6.16	0.01	0.07	0.000004	79.27
75th percentile	1.90	17.80	118.25	0.23	35.06	0.05	0.20	0.000011	92.36
WQ Guideline	25	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Table D-13: Water Quality Performance for Nickel (Ni) for LV-4

Starting Date and Time	Effluent EMC (µg/L)	Precipitation Depth (mm)	Total Estimated Influent Volume (m^3)	Total Estimated Influent Load (g)	Total Measured Effluent Volume (m^3)	Total Measured Effluent Load (g)	Estimated Pollutant Load Reduction		
							(g)	Normalized (g/m^2)	(%)
2013-06-10 7:50:00	15.6	33.0	51428.9	0.07714	1475.4	0.02302	0.0541270	0.0000131	70.2
2013-07-08 16:10:00	17.3	81.6	127169.5	0.19075	151521.0	2.62131	-2.4305590	-0.0005899	-1274.2
2014-04-29 7:20:00	13.3	41.4	64519.8	0.09678	14636.4	0.19466	-0.0978844	-0.0000238	-101.1
2014-07-27 18:50:00	13.5	33.6	52363.9	0.07855	5895.6	0.07959	-0.0010447	-0.0000003	-1.3
2014-09-05 19:00:00	14.1	34.0	52987.3	0.07948	15179.4	0.21403	-0.1345486	-0.0000327	-169.3

2015-06-27 10:40:00	11.1	54.0	84156.3	0.12623	19193.4	0.21305	-0.0868123	-0.0000211	-68.8
count	6	6	6	6	6	6	6	6	6
average	14.15	46.27	72104.29	0.11	34650.20	0.56	-0.45	-0.000109	-257.42
median	13.80	37.70	58753.57	0.09	14907.90	0.20	-0.09	-0.000022	-84.96
25th percentile	13.35	33.70	52519.77	0.08	8080.80	0.11	-0.13	-0.000030	-152.25
75th percentile	15.23	50.85	79247.18	0.12	18189.90	0.21	-0.02	-0.000005	-18.19
WQ Guideline	25	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Table D-14: Water Quality Performance for Zinc (Zn) for LV-2

Starting Date and Time	Effluent EMC (mg/L)	Precipitation Depth (mm)	Total Estimated Influent Volume (m^3)	Total Estimated Influent Load (g)	Total Measured Effluent Volume (m^3)	Total Measured Effluent Load (g)	Estimated Pollutant Load Reduction		
							(g)	Normalized (g/m^2)	(%)
2013-04-08 15:20:00	190	10.8	71.7	7.78462	11.9	2.25617	5.5284	0.00032	71.0
2013-04-09 15:10:00	71	67.8	450.4	48.87011	238.3	16.91899	31.9511	0.00183	65.4
2013-04-24 10:30:00	41	14.4	95.7	5.15148	30.2	1.23962	3.9119	0.00022	75.9
2013-04-28 17:30:00	30.6	12.2	81.0	4.36445	22.6	0.69147	3.6730	0.00021	84.2
2013-05-10 8:50:00	55.5	22.0	146.2	7.87032	62.5	3.46760	4.4027	0.00025	55.9
2013-05-20 21:40:00	92	7.2	47.8	2.57574	4.9	0.44734	2.1284	0.00012	82.6
2013-05-31 17:00:00	61	4.0	26.6	1.43097	6.0	0.36574	1.0652	0.00006	74.4
2013-06-13 9:30:00	30.9	5.2	34.5	1.86026	3.0	0.09337	1.7669	0.00010	95.0
2013-06-16 5:10:00	44.6	10.8	71.7	3.86361	22.0	0.97920	2.8844	0.00016	74.7
2013-07-07 0:30:00	433	5.6	37.2	2.00335	1.0	0.41776	1.5856	0.00009	79.1
2013-07-19 17:10:00	75.3	12.6	83.7	4.50755	4.7	0.35620	4.1513	0.00024	92.1
2013-08-02 15:10:00	36.9	3.6	23.9	1.28787	0.0	0.00000	1.2879	0.00007	100.0
2013-08-26 3:40:00	80.4	15.4	102.3	5.50922	3.3	0.26903	5.2402	0.00030	95.1
2013-08-27 17:30:00	27.5	20.2	134.2	7.22638	22.0	0.60469	6.6217	0.00038	91.6
2013-09-20 22:00:00	30.7	34.0	225.9	12.16322	2.8	0.08549	12.0777	0.00069	99.3
2013-10-31 3:20:00	35.3	13.6	90.3	4.86529	1.1	0.03980	4.8255	0.00028	99.2
2014-04-04 10:10:00	120	9.2	61.1	6.63134	6.9	0.82670	5.8046	0.00033	87.5
2014-04-07 17:00:00	97	17.4	115.6	12.54189	36.7	3.55724	8.9846	0.00051	71.6
2014-04-12 23:20:00	69	7.4	49.2	5.33391	6.7	0.45979	4.8741	0.00028	91.4

2014-05-13 3:30:00	79.4	14.6	97.0	5.22303	48.5	3.85384	1.3692	0.00008	26.2
2014-05-13 19:00:00	46.7	4.0	26.6	1.43097	20.5	0.95912	0.4718	0.00003	33.0
2014-05-14 17:00:00	40.4	10.2	67.8	3.64897	65.9	2.66400	0.9850	0.00006	27.0
2014-05-15 10:30:00	39.5	17.8	118.3	6.36780	115.5	4.56166	1.8061	0.00010	28.4
2014-06-17 17:50:00	37.4	10.8	71.7	3.86361	14.8	0.55490	3.3087	0.00019	85.6
2014-06-25 17:40:00	38	16.8	111.6	6.01006	14.1	0.53573	5.4743	0.00031	91.1
2014-08-11 22:50:00	28	23.4	155.5	8.37116	43.1	1.20800	7.1632	0.00041	85.6
2014-09-02 11:30:00	47.3	11.2	74.4	4.00671	12.8	0.60438	3.4023	0.00019	84.9
2014-09-10 15:50:00	28.8	17.8	118.3	6.36780	25.9	0.74589	5.6219	0.00032	88.3
2014-09-20 21:40:00	28.6	15.6	103.6	5.58077	21.3	0.61036	4.9704	0.00028	89.1
2014-10-07 16:20:00	27.8	12.4	82.4	4.43600	2.2	0.06068	4.3753	0.00025	98.6
2014-11-24 0:00:00	74.5	19.6	130.2	14.12764	24.7	1.83690	12.2907	0.00070	87.0
2015-04-08 10:20:00	80	14.8	98.3	10.66781	18.9	1.51051	9.1573	0.00052	85.8
2015-04-09 14:50:00	65.3	16.2	107.6	11.67693	45.6	2.97717	8.6998	0.00050	74.5
2015-04-19 22:40:00	39.8	20.0	132.9	7.15483	80.7	3.21322	3.9416	0.00023	55.1
2015-04-21 11:50:00	54.3	7.2	47.8	2.57574	16.5	0.89351	1.6822	0.00010	65.3
2015-05-30 12:50:00	71	47.8	317.5	17.10005	24.4	1.73399	15.3661	0.00088	89.9
2015-06-27 10:40:00	24.8	54.0	358.7	19.31805	135.8	3.36789	15.9502	0.00091	82.6
2015-07-07 12:40:00	53	14.6	97.0	5.22303	12.3	0.65320	4.5698	0.00026	87.5
count	38	38	38	38	38	38	38	38	38
average	66.48	16.90	112.27	7.61	32.37	1.73	5.88	0.00034	77.67
median	47.00	14.50	96.33	5.42	19.71	0.79	4.49	0.00026	85.24
25th percentile	35.70	10.35	68.76	3.90	6.16	0.45	2.32	0.00013	72.34
75th percentile	73.63	17.80	118.25	7.85	35.06	2.15	6.42	0.00037	90.78
WQ Guideline	20	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Table D-14: Water Quality Performance for Zinc (Zn) for LV-4

Starting Date and Time	Effluent EMC (µg/L)	Precipitation Depth (mm)	Total Estimated Influent Volume (m^3)	Total Estimated Influent Load (g)	Total Measured Effluent Volume (m^3)	Total Measured Effluent Load (g)	Estimated Pollutant Load Reduction		
							(g)	Normalized (g/m^2)	(%)
2013-06-10 7:50:00	15.6	33.0	51428.9	2.76944	1475.4	0.02302	2.7464273	0.0006666	99.2
2013-07-08 16:10:00	26	81.6	127169.5	6.84808	151521.0	3.93955	2.9085327	0.0007060	42.5
2014-04-29 7:20:00	23	41.4	64519.8	3.47439	14636.4	0.33664	3.1377556	0.0007616	90.3
2014-07-27 18:50:00	14.3	33.6	52363.9	2.81980	5895.6	0.08431	2.7354901	0.0006640	97.0
2014-09-05 19:00:00	16	34.0	52987.3	2.85337	15179.4	0.24287	2.6104957	0.0006336	91.5
2015-06-27 10:40:00	12.4	54.0	84156.3	4.53182	19193.4	0.23800	4.2938187	0.0010422	94.7
count	6	6	6	6	6	6	6	6	6
average	17.88	46.27	72104.29	3.88	34650.20	0.81	3.07	0.000746	85.87
median	15.80	37.70	58753.57	3.16	14907.90	0.24	2.83	0.000686	93.12
25th percentile	14.63	33.70	52519.77	2.83	8080.80	0.12	2.74	0.000665	90.61
75th percentile	21.25	50.85	79247.18	4.27	18189.90	0.31	3.08	0.000748	96.44
WQ Guideline	20	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

LAKEVIEW, CITY OF MISSISSAUGA

LOW IMPACT DEVELOPMENT INFRASTRUCTURE PERFORMANCE AND RISK MANAGEMENT ASSESSMENT

Appendix E
Site Maintenance and Inspection Logs

NOTICE

DRAFT REPORT

1 SITE INSPECTION LOG DEVELOPMENT

A site inspection log was developed to quantitatively record site conditions and maintenance needs as accurately as possible. The goal of the checklist log format is to make inspections easy and straightforward for anyone to complete. There is a corresponding legend to accompany the checklist to give guidance to someone who may not be familiar with LID, such as maintenance and landscaping staff. The same information is collected each time in the same format, ensuring proper documentation and making it easier to track changes over time which gives consistency to the monitoring. By reviewing the logged data over time you can determine the frequency of maintenance needed for each site and provide insight into future designs and planning of LID features. Developing a maintenance schedule based on data gathered at the site, allows for the establishment of maintenance costs, which are important to the functionality and life cycle of LID features.

Figure 1-1: CVC staff completing an LID inspection log at our Lakeview site

2 SITE INSPECTION LOG

Below is the inspection log template used by monitoring staff to note current conditions of the site as well as maintenance needs during routine site visits. A photo log is kept to supplement this information. Three photos are usually taken from different vantage points to document the current site conditions, and additional features or issues are photographed as necessary.

LID Inspection Checklist

Site: Lakeview

Inspector: ______________________________

Date: __________________________________

Site Characteristics:

Lakeview Bioretention Cells	
Drainage Area	Street
Soil Media	Engineered bioretention mix
Pretreatment	Permeable pavement and grass swale
Hydraulic Configuration	Online
Inlet Type	Curb cuts and permeable pavement driveways

Contributing Drainage Area:		**Category:**	**Notes:**
% of Trash/Debris Present	0% --- 5% --- 10% --- 15% --- 20% +		
% of Sediment Accumulation	0% --- 5% --- 10% --- 15% --- 20% +		
Inlets:			
% of Trash/Debris Present	0% --- 5% --- 10% --- 15% --- 20% +		
% of Sediment Accumulation	0% --- 5% --- 10% --- 15% --- 20% +		
% of Erosion	0% --- 5% --- 10% --- 15% --- 20% +		
Structural damage?	Yes or No		
Is inlet clear and able to accept incoming flow?	Yes or No		
Facility:			
% of Trash/Debris Present	0% --- 5% --- 10% --- 15% --- 20% +		
Evidence of Ponding	Yes or No		
% of Area Ponding	0% --- 5% --- 10% --- 15% --- 20% +		
Approximate Depth of	________________________		

Ponding	
% of Bare/Exposed Soil	0% --- 5% --- 10% --- 15% --- 20% +
% of Sediment Accumulation	0% --- 5% --- 10% --- 15% --- 20% +
% of Erosion	0% --- 5% --- 10% --- 15% --- 20% +
Permeable Pavement:	
% of Trash/Debris Present	0% --- 5% --- 10% --- 15% --- 20% +
% of Sediment Accumulation	0% --- 5% --- 10% --- 15% --- 20% +
Structural damage?	Yes or No
Area of broken/cracked/ heaving pavers or curbs?	0% --- 5% --- 10% --- 15% --- 20% +
Evidence of Clogging	Yes or No
Outlet:	
% of Trash/Debris Present	0% --- 5% --- 10% --- 15% --- 20% +
% of Erosion	0% --- 5% --- 10% --- 15% --- 20% +
% of Sediment Accumulation	0% --- 5% --- 10% --- 15% --- 20% +
Structural damage?	Yes or No
Is outlet clear and able to accept overflow?	Yes or No
Non-LID Feature:	
Sign on Site	Yes or No
Damage to Sign	Yes or No
Vegetation (changes seasonally):	
% Vegetation Cover	0% --- 25% --- 50% --- 75% --- 100%
% Dead Vegetation	0% --- 5% --- 10% --- 15% --- 20% +
% of Invasives/Weeds	0% --- 5% --- 10% --- 15% --- 20% +
Winter Conditions:	
% Snow Cover	0% --- 5% --- 10% --- 15% --- 20% +
Approximate Depth of Snow	______________________
Maintenance:	
Is maintenance required?	Yes or No
What needs to be done?	______________________

How much time was spent on maintenance? ______________________

Regular maintenance, long-term maintenance or emergency maintenance? ______________________

Who is responsible? ______________________

How often is regular maintenance done? ______________________

Photos:

Number of Photo	Description/Notes

Site Comments:

3 RESULTS

The documentation of site conditions began in 2012 and is still underway. The site inspection log above has been filled out approximately monthly for the past four years and the data has been compiled into a database. Specific features of the LID site were isolated so that they could be tracked overtime to see if any patterns or issues followed a trend. Hopefully this will aid in future designs as we can track problems over the lifetime of the facility and see if the surrounding environment and location has an effect on their functionality, or if a different style of feature is generally more successful than others.

The inspection log uses percentages as it was easier to visually relate the area covered to a percent cover of the facility or feature. A corresponding legend goes with the inspection log, which provides photos of different examples of each feature and its condition related to a percentage. This will provide guidance to the inspector who is completing the log, hopefully resulting in more consistent and accurate recording of conditions. Different features have a different threshold which would trigger the need for maintenance activities, as some features are more crucial to the overall functionality of the LID facility. Generally if 20 per cent or greater is observed for a feature it is considered a fail and falls under the “severe” category, which should trigger immediate action to correct the issue.

Table 3-1 shows a summary of the data collected at Lakeview for both of the LID streets that were retrofitted. All of the data was compiled and then averaged for each category, in order to report on a total average per cent for each feature of the LID facility that was inspected. A “conditions” category was then assigned to each feature based on the average per cent value calculated. At Lakeview there were four features over the past two years that were consistently “good”, which were Contributing Drainage Area Trash/Debris, LID Facility Trash/Debris Cover, Outlet Sediment Accumulation, and Vegetation Weeds/Invasive Cover. The neighborhood usually does not have an issue with trash and garbage as it is mostly residential, resulting in tidy LID features as there is only trash and debris cover present about 75 per cent of the time. Most of the debris is found in the fall and spring as there are many mature trees in the area that lose their leaves, as well as old dormant vegetation debris that is present in the spring before the new growth comes through. Fortunately there are no categories that fall into the “severe” rating with the compiled data, as the Lakeview LID features are generally well maintained and never get to that condition.

Overall the Lakeview LID features are fairly well maintained by the residents, although there are variations between homes. The majority of the time the features fall into the “good” or “mild” condition categories, with only two features (both inlet related) falling into the “moderate” category. With the collection of additional data a more rigorous analysis will be performed and aid in the life-cycle costing analysis of LID features, and how maintenance relates to functionality over time.

Table 3-1: LID Inspection Log Data Collected for Lakeview from 2012 to 2014 for both Streets

Inspected Feature of LID Site	Conditions Based on Average Per Cent Values	Per Cent Good	Per Cent Mild	Per Cent Moderate	Per Cent Severe
Contributing Drainage Area Sediment	Mild	59%	41%	0%	0%
Contributing Drainage Area Trash/Debris	Good	100%	0%	0%	0%
LID Facility Sediment Cover	Mild	75%	25%	0%	0%
LID Facility Trash/Debris Cover	Good	75%	13%	6%	6%
Inlets Sediment Accumulation	Moderate	21%	46%	15%	17%
Inlets Trash/Debris Accumulation	Moderate	29%	38%	19%	13%
Outlets Sediment Accumulation	Good	98%	2%	0%	0%
Outlets Trash/Debris Accumulation	Mild	90%	8%	0%	2%
Vegetation Weeds/Invasive Cover	Good	75%	25%	0%	0%

4 DOCUMENTATION OF MAINTENANCE ACTIVITIES AND COSTS

Because of the significance of maintenance over the life of an LID facility, in terms of performance, appearance and cost, and the fact that documentation of actual maintenance costs for bioretention facilities is lacking in the region (and across most of North America), documentation of maintenance is a critical component of the stormwater monitoring that is being conducted at Lakeview. To document maintenance, CVC will evaluate and note maintenance needs during site visits and will coordinate with those responsible for performing maintenance and repair to maintain a record of maintenance activities and costs. The following data collection efforts will aid in characterizing maintenance requirements and costs:

- Take photos from reference locations at the site every time an inspection log is completed (usually monthly, but sometimes more frequently in the growing season to track vegetation health) and before and after maintenance.
- Keep logs of site visits, inspections and maintenance dates, activities performed, observations and associated costs.
- Look for common issues and maintenance tasks associated with LID such as trash accumulation, sediment deposition, erosion, and vegetation health to watch for changes over time.
- Inspect different areas of the LID feature such as the drainage area, inlets, outlets, and vegetation, to ensure nothing is overlooked and that the site can perform optimally.
- Outline any maintenance issues that need to be addressed and whether they are urgent or routine so that the appropriate actions can take place.
- Monitor the duration of standing water in the bioswales periodically. As the duration of standing water grows longer, it will be a sign that infiltration capacity is reduced and maintenance may be needed.

Tracking maintenance tasks at Lakeview has been challenging as the first two years after construction, the contractors who retrofitted the site were responsible for routine establishment maintenance. As a part of their contract they were supposed to weed the bioswales each growing season, water the establishing plants in times of extended dry periods, and ensure the site was tidy and free of trash and debris. After the two-year establishment period the contractors were no longer responsible for the maintenance of the site as the City of Mississauga assumed the LID features as their own since they fall on city property. Both the bioswales and permeable pavement driveway sections fall within the road-right-of-way, making them City property, but it is up to the residents to maintain these features. Initially there was a bit of confusion between the residents of Lakeview as they were unsure of what they were responsible for, and in the third year some maintenance issues arose.

5 BIORETENTION MAINTENANCE

A brief description of maintenance activities for Lakeview is provided along with the inspection log used by CVC monitoring staff for site inspections.

The primary maintenance objective for bioretention practices is to keep vegetation healthy, remove sediments and trash, and ensure that the facility is draining properly (i.e. inlets and outlet can accept flow). The growing medium may need to be replaced eventually to maintain performance. Typical recommended maintenance activities for bioretention cells include the following[7]:

- Inspect the infiltrating surface at least twice annually following precipitation events to determine if the bioretention area is providing acceptable infiltration. If standing water persists for more than 24 hours after runoff has ceased, clogging should be further investigated and remedied. Additionally, check for erosion and repair as necessary.
- Remove debris and litter from the infiltrating surface to minimize clogging of the media. Remove debris and litter from the overflow structure.
- Maintain healthy, weed-free vegetation. Weeds should be removed before they flower. The frequency of weeding will depend on the planting scheme and cover. When the growing media is covered with mulch or densely vegetated, less frequent weeding will be required.
- Replace mulch (hardwood recommended) only when needed to maintain a mulch depth of up to approximately 75 mm.
- If ponded water is observed in a bioretention cell more than 24 hours after the end of a runoff event, check underdrain outfall locations and clean-outs for blockages. Maintenance activities to restore infiltration capacity of bioretention facilities will vary with the degree and nature of the clogging.
    - If clogging is primarily related to sediment accumulation on the filter surface, infiltration may be improved by removing excess accumulated sediment and scarifying the surface of the filter with a rake.

If the clogging is due to migration of sediments deeper into the pore spaces of the media, removal, safe disposal, and replacement of all or a portion of the media may be required. The frequency of media replacement will depend on site-specific pollutant loading characteristics. Since bioretention technologies have only recently seen more widespread application, the frequency of media replacement has not yet been well established. Although surface clogging of the media is expected over time, established root systems promote infiltration. This means that mature vegetation that covers the filter surface should increase the life span of the growing media, serving to promote infiltration even as the media surface clogs.

7Urban Drainage and Flood Control District (UDFCD). 2010. Urban Storm Drainage Criteria Manual, Volume 3

Table 5-1: Estimated Costs for Plant Species that have been used in the Lakeview Bioretention Swales

Plant Species	Flowering Season	Estimated Cost
Blue flag iris	May-June	$14.95
Great lobelia	July-Sept	$14.95
Bee Balm	July-August	$15.95
Obedient Plant	June-Sept	$14.95
Butterfly milkweed	June-August	$14.95
Sapphire blue oat grass	June	$16.95
Yellow tickseed	May-June	$14.95
Goblin blanket flower	June-Sept	$15.95
Porcupine sedge	June-July	$16.95
Black-eyed Susan	June-Sept	$14.95
Siberian bugloss	May-June	$18.95
Wild geranium	May-June	$16.95

6 PERMEABLE PAVEMENT MAINTENANCE

The key maintenance objective for a permeable pavement system is to know when runoff is no longer rapidly infiltrating into the surface, which is typically due to void spaces becoming clogged and requiring sediment removal. Inspect pavement condition and observe infiltration at least annually, either during a rain event or with a garden hose to ensure that water infiltrates into the surface. Video, photographs, or notes can be helpful in measuring loss of infiltration over time. Typical recommended maintenance activities for bioretention cells include[1]:

- Debris should be removed, routinely, as a source control measure, and sweeping is recommended as a part of an ongoing maintenance program. This is frequently performed with a broom sweeper. Although this type of sweeper can be effective at removing solids and debris from the surface, it will not remove solids from the void space of a permeable pavement. Use a vacuum or regenerative air sweeper to help maintain or restore infiltration. If the pavement has not been properly maintained, a vacuum sweeper will likely be needed.
- Use a regenerative air or vacuum sweeper after any significant site work (e.g., landscaping) and approximately twice per year to maintain infiltration rates. This should be done on a warm dry day for best results. Do not use water with the sweeper. The frequency is site specific and inspections of the pavement may show that biannual vacuuming is more frequent than necessary.
- In general, permeable pavements do not form ice to the same extent as conventional pavements. Because of this and the character of water drainage from permeable pavement surfaces, much less salt is required compared to asphalt surfaces. Simply stated, when water drains off of asphalt, salt can dissolve and become part of the solution and little to no residual salt granules remain. When water drains off of permeable pavement, it drains to the nearest permeable pavement joint,

therefore there is less of an opportunity for the salt to dissolve, increasing the potential for salt granules to remain on the permeable pavement surface after the water has drained. Similarly, conventional liquid treatments (deicers) will not stay at the surface of a permeable pavement as needed for the treatment to be effective. Sand should not be applied to a permeable pavement as it can reduce infiltration. Plowing is the recommended snow removal process. Conventional plowing operations should not cause damage to the pavements. Deicers may be used; however, they may not be effective for the reason stated above. Sand should not be used. If sand is accidently used, use a vacuum sweeper to remove the sand.

- Permeable pavers, when installed correctly, should have a long service life. If a repair is required, it is frequently due to poor placement of the paver blocks. Follow industry guidelines for installation and replacement after underground repairs. If surface is completely clogged and rendering a minimal surface infiltration rate, restoration of surface infiltration can be achieved by removing the first 12-25 mm of soiled aggregate infill material with a vacuum sweeper. After cleaning, the openings between the pavers will need to be refilled with clean aggregate infill materials. Replacement of the infill is best accomplished with push brooms.

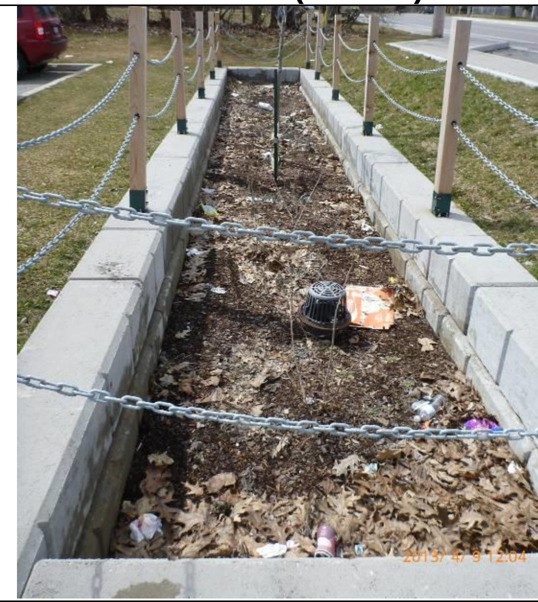
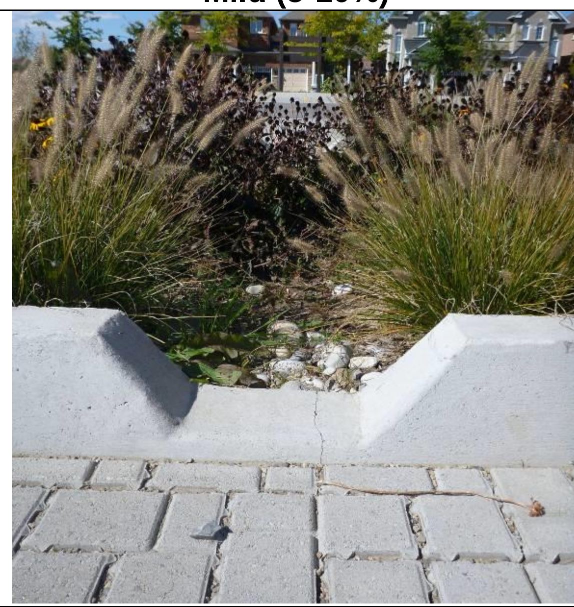
Table 6-1: Routine Maintenance Estimates based on Maintenance Schedule from TRCA's Low Impact Development Stormwater Practice Inspection and Maintenance Guide Draft 2015

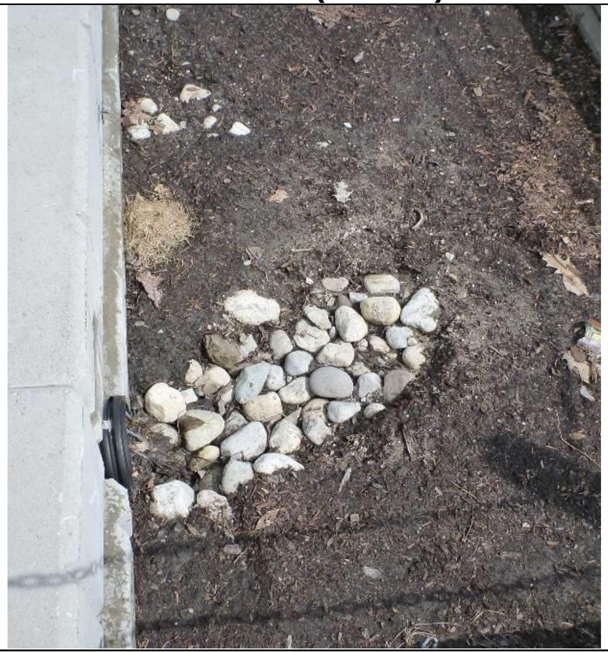
Component	Routine Maintenance Task*	Minimum Frequency*	High Frequency*	Potential Associated Costs	Quantities required
Rain gardens	Replace dead/diseased plants to maintain >80% vegetation cover	Annually	Biannually	Cost of plants range in price from ~$2-20 for potted plants, depending on species and where they are purchased from**	After the establishment period is over, only a few plants would need to be replaced each year
	Add mulch to maintain 5-10cm depth on non-vegetated areas	Every 2 Years	Every 2 Years	Cost of mulch as an estimate shredded mulch is available in 3 ft^3 bags for less than $10, or by bulk from a garden center in a quantity of 27ft^3 for ~$120	The average area of the bioswales is approximately 20m^2, this means that 1-2.5 m^3 of mulch would be required depending on depth. This would require approximately 12-29 bags of mulch. And the 27ft^3 bulk order would probably suffice.
	Remove trash/debris from	Biannually	Quarterly		

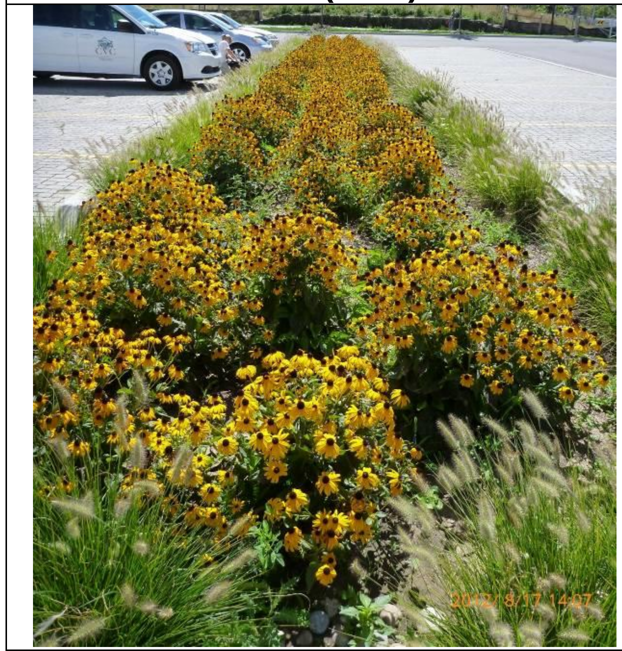
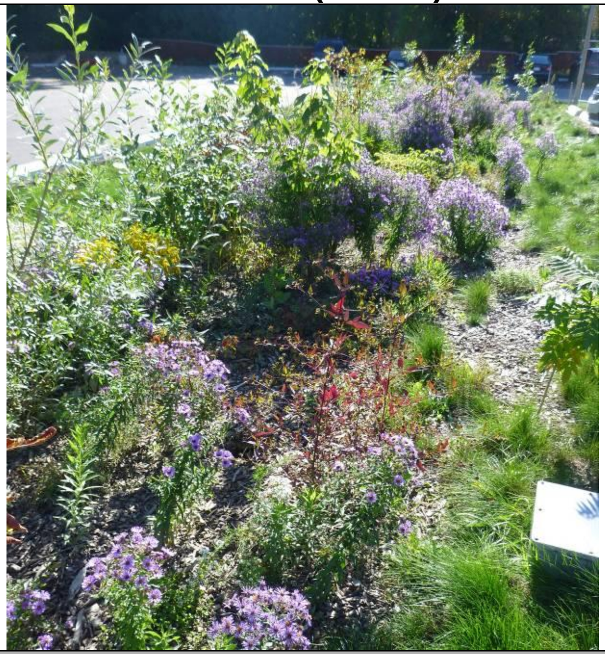
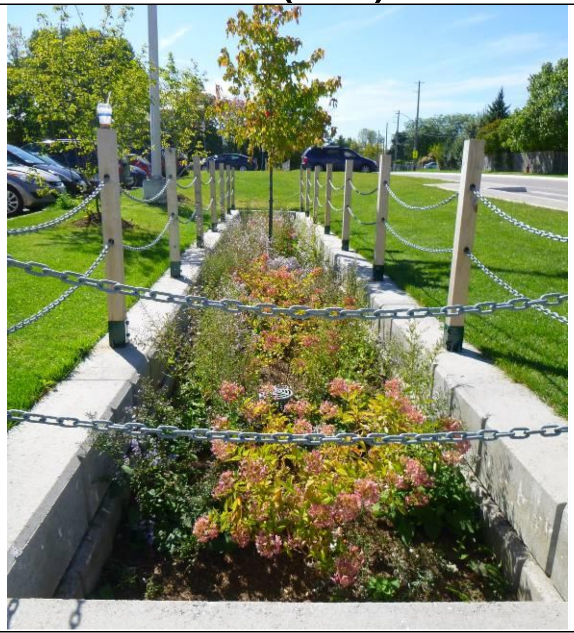
	inlets and gardens				
	For sod, mow grass to maintain height between 10-15cm	Monthly	Bi-monthly		
	Weeding	Biannually	Quarterly		
	Pruning/Thinning of plants	Annually	Annually		
Permeable Pavements	Remove trash/natural debris/clippings/sediment from contributing area and pavers	Biannually	Quarterly		
	Remove accumulated sediment by sweeping/vacuuming	Annually	Biannually	Vacuuming could be done with a shop vacuum which cost $~70-$160 at a local hardware store (Lowes)	
	Replace/top up joint material	Annually	Biannually	Lakeview maintenance factsheet specifies 2-5mm clean-washed pea gravel. Pea gravel is available from Canadian Tire for ~$6 for a 18kg bag, however they do not provide precise specifications for it. ¼" Pea gravel is available from a local garden center for ~$130 for 0.76m^3. If bought in bulk can be purchased for $34-55 /tonne	1 bag/year would likely be required. The average area of permeable pavers is approximately 25 m^2, however it is unlikely that this entire area would require top up/replacement each year.
	Weeding any plants growing in cracks	Annually	Biannually		

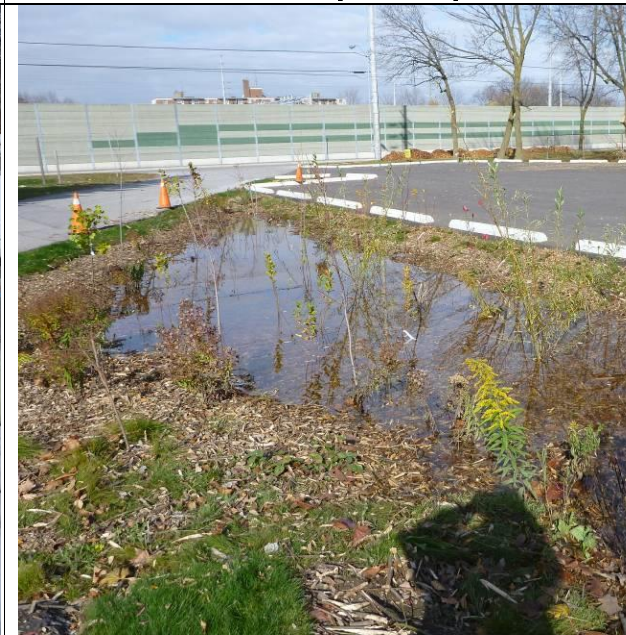
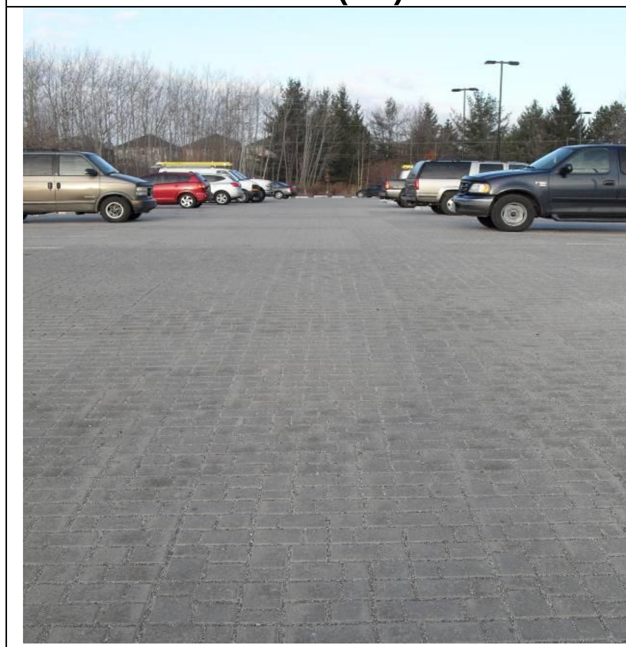
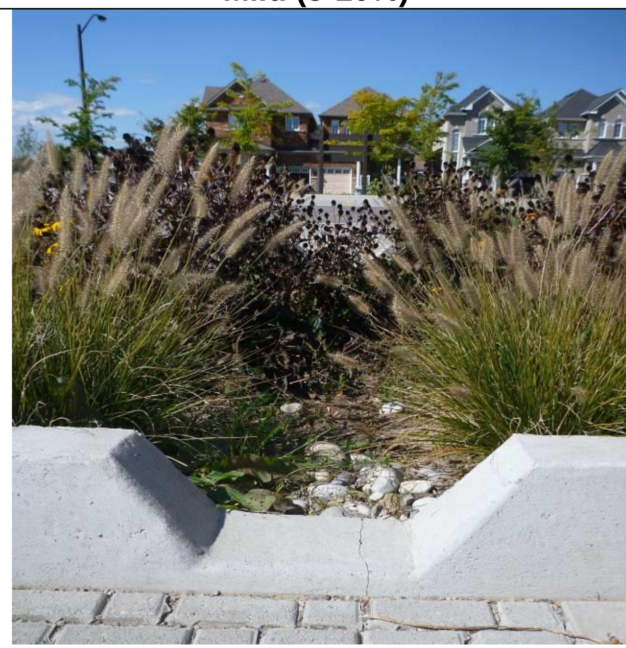
*routine maintenance tasks and schedule from section on bioretention maintenance in *Low Impact Development Stormwater Practice Inspection and Maintenance Guide Draft 2015* published by TRCA and Sustainable Technologies
**prices estimated based on quotes/online prices from southern Ontario nurseries, including one in Mississauga
***prices estimated from garden centre websites in Mississauga and hardware stores

LID Inspection Checklist Legend

Trash and Debris			
Good (0-5%)	Mild (5-10%)	Moderate (10-15%)	Severe (+ 20%)
			
Inlet Blockage			
Good (0-5%)	Mild (5-10%)	Moderate (10-15%)	Severe (+ 20%)
			

Erosion			
Good (0-5%)	**Mild (5-10%)**	**Moderate (10-20%)**	**Severe (+ 20%)**
			
Sediment Accumulation			
Good (0-5%)	**Mild (5-10%)**	**Moderate (10-15%)**	**Severe (+ 20%)**
			

Vegetation (Invasive/Weeds)			
Good (0-5%)	**Mild (5-10%)**	**Moderate (10-15%)**	**Severe (+ 20%)**
			
Vegetation Cover			
Good (>75%)	**Mild (65-75%)**	**Moderate (50-65%)**	**Severe (0-50%)**
			

Ponding Area			
Good (0-5%)	**Mild (5-10%)**	**Moderate (10-15%)**	**Severe (+ 20%)**
			
Structural Damage			
Good (0%)	**Mild (5-10%)**	**Moderate (10-15%)**	**Severe (+20%)**
			

Outlet Blockage			
Good (0-5%)	**Mild (5-10%)**	**Moderate (10-15%)**	**Severe (+ 20%)**
			

LAKEVIEW, CITY OF MISSISSAUGA

LOW IMPACT DEVELOPMENT INFRASTRUCTURE PERFORMANCE AND RISK MANAGEMENT ASSESSMENT

Appendix F

Intensification of Urban Water Cycle

NOTICE

The contents of this report do not necessarily represent the policies of the supporting agencies. Although every reasonable effort has been made to ensure the integrity of the report, the supporting agencies do not make any warranty or representation, expressed or implied, with respect to the accuracy or completeness of the information contained herein. Mention of trade names or commercial products does not constitute endorsement or recommendation of those products.

DRAFT REPORT

1 INTENSIFICATION OF URBAN WATER CYCLE

It is expected that the population of the Greater Toronto Area (GTA) will grow from 6.4 million in 2012 to 8.9 million by 2036[1]. This ongoing urbanization of our environment by increasing imperviousness results in a phenomenon commonly known as the "urban stream syndrome"[2], where hydrographs become flashier (i.e., increased flow variability), baseflow decline, water quality is degraded, stream channels are eroded, water temperatures rise, and biological richness declines. **Figure 1-1** shows a hydrograph comparing stream flow rates before, during, and after a storm under pre- and post-development conditions[3]. As indicated, streams with developed watersheds have substantially higher peak flows, and these peak flows occur more quickly than under predevelopment conditions. This is reflective of typical urban conditions, where runoff moves quickly over impervious surfaces and drains into a channel.

Impervious surfaces such as streets, sidewalks and driveways contribute 65-75% of total loadings of suspended solids, total phosphorus, and metals to our receiving streams and lakes (Bannerman et al., 1992). Furthermore, beach closures and reductions in recreational fishing due to pollutant loading from urban stormwater and have resulted in up to $87 million a year in lost revenue to local economies (Marbek, 2010).

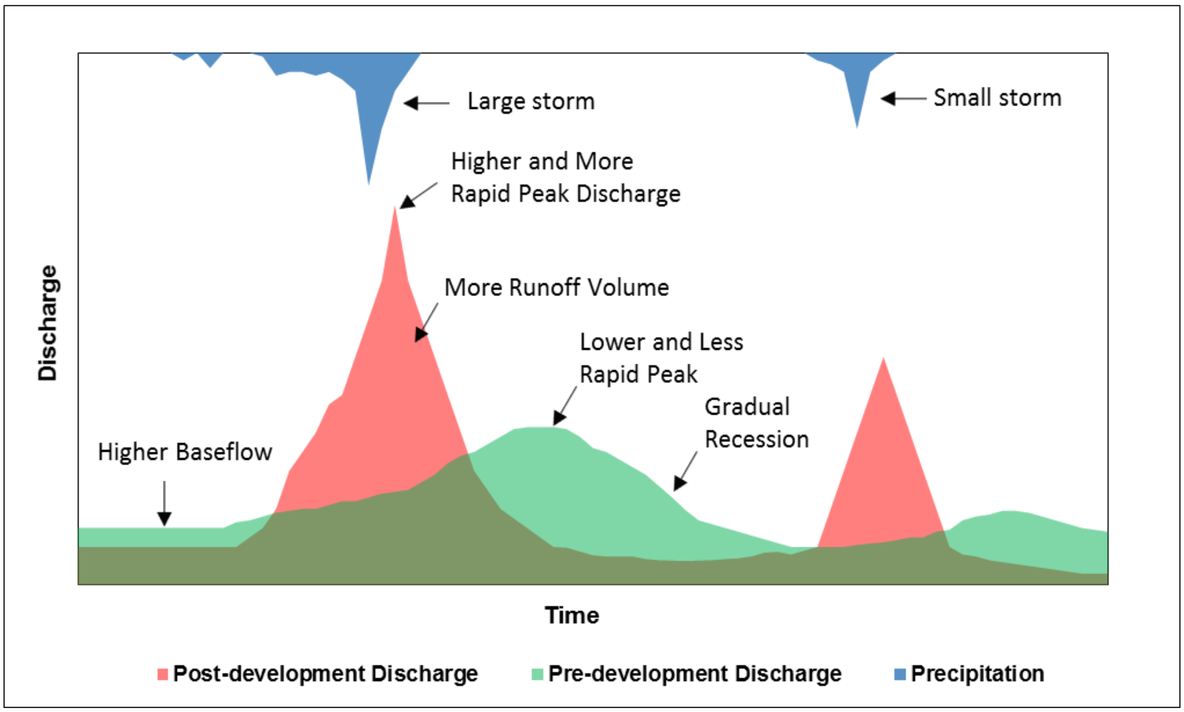


Figure 1-1: Changes in stream flow hydrograph as a result of urbanization (adapted from Schueler, 1987)

[1] Ministry of Finance (MOF). 2013. Ontario Population Projections Update. http://www.fin.gov.on.ca/en/economy/demographics/projections/projections2012-2036.pdf

[2] Walsh CJ, Roy AH, Feminella JW, Cottingham PD, Groffman PM, Morgan RP II. 2005. The urban stream syndrome: Current knowledge and the search for a cure. Journal of the North American Benthological Society 24(3):706-723

[3] Schueler, T. 1987. Controlling Urban Runoff: A Practical Manual for Planning and Designing Urban Best Management Practices. Metropolitan Washington Council of Governments, Washington, DC.

This ongoing urbanization of our environment by increasing imperviousness also corresponds to a significant alteration to the water cycle. Continued development with structured conveyance and impervious pathways redistributes the water budget to favour runoff over evaporation, infiltration, and recharge for streams and groundwater. The figures below illustrate how four important components in the water cycle are affected by increasing levels of imperviousness[4].

In natural and rural environments with vegetated soils, surface runoff is generally low and represents a low fraction (10 to 20%) of the total fallen precipitation[5]. Water either percolates into the ground or is returned to the atmosphere by evaporation and transpiration. A considerable percentage of the rainfall infiltrates into the soil and contributes to the groundwater. The local water table is often connected to nearby streams, providing seepage to streams and wetlands during dry periods and maintaining base flow essential to the biological and habitat integrity of streams. Water that is evaporated into the atmosphere behaves like an air conditioner for the urban atmosphere, thereby more water in the atmosphere reduces the urban heat island effect, mitigating high air temperatures (**Figure 1-2a).**

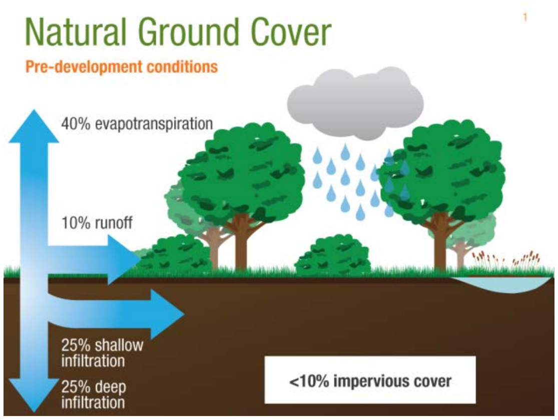


Figure 1-2a: Natural ground cover pre-development conditions with less than 10% impervious cover.

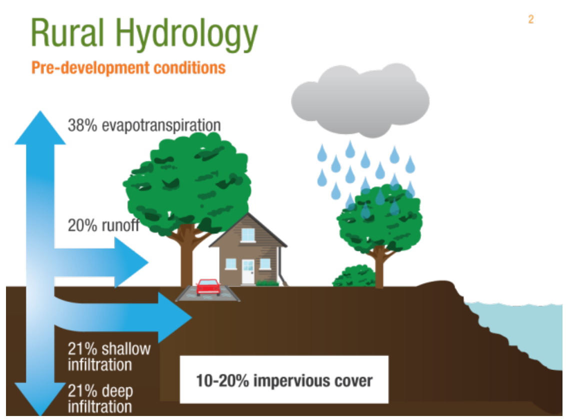


Figure 1-2b: Rural hydrology pre-development conditions with 10 to 20% impervious cover.

(Adapted from FIRSWG, 1998)

Land development converts permeable land into increasing impermeable surfaces. During urbanization, natural channels are replaced by artificial drainage pipes and channels that decrease the amount of water infiltration and storage within the soil column. This alters the hydrologic regime by allowing less rainfall infiltration into the ground, and more channeled runoff through the urban infrastructure**.** Alterations to site runoff characteristics can cause an increase in the volume and frequency of runoff flows (discharge), velocities that cause flooding, and accelerated erosion **(Figure 1-2c)**. This also decreases the amount of water available for evapotranspiration and infiltration. Evaporation decreases because there is less time for it to occur when runoff moves quickly off impervious surfaces. Transpiration decreases because vegetation has been removed. In addition, urban infrastructure removes water from shallow ponds and wetlands that could have otherwise been used to replenish the water table and maintain low flow conditions in local watercourses. Headwater streams, with small contributing drainage areas, are especially sensitive to localized changes in groundwater recharge and base flow.

[4] Adapted from Federal Interagency Stream Restoration Working Group (FISRWG). 1998. Stream CorridorRestoration: Principles, Processes, and Practices. PB98-158348LUW.

[5] Prince George's County, Maryland Department of Environmental Resources Programs and Planning Division. 1999. Low-Impact Development Hydrologic Analysis

As a much larger percentage of rainwater hits impervious surfaces including roofs, sidewalks, parking lots, driveways, and streets, it must be controlled through storm water management techniques. Traditional approaches have focused on collection and conveyance to quickly transport stormwater to the nearest watercourse to prevent property damage (**Figure 1-2c**). Provincial requirements currently require stormwater management to take an "end of pipe" approach, using gutters and piping systems to carry rainwater into ponds or detention basins **(Figure 1-2d)**. This approach does not mitigate or alter the runoff volume component of the water cycle which is the driving force over flood risk and drought due to decreases in subsurface flows.

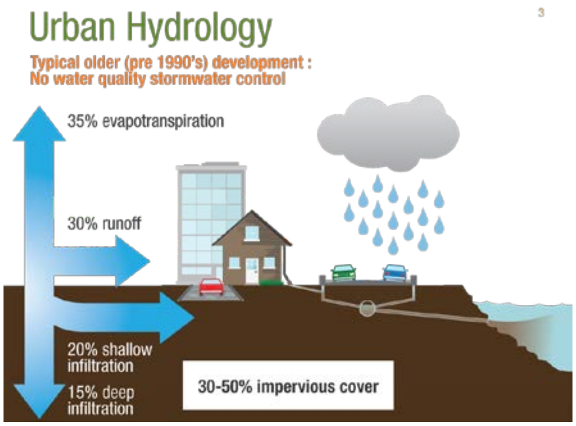


Figure 1-2c: Stormwater Management with no water quality control

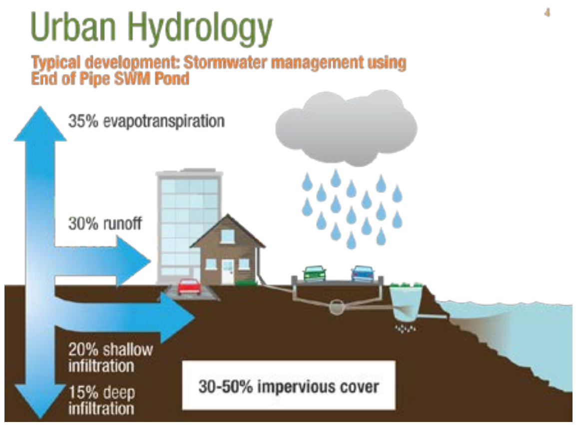


Figure 1-2d: Stormwater management using SWM ponds.

Urban areas are particularly susceptible to flooding due to a high concentration of impervious surfaces that channel precipitation runoff into the city's underground infrastructure. During rainfall events of high intensity, duration and/or frequency, the runoff component of the water balance will be overwhelmed and not mitigated by infiltration, creating flood-prone areas in urbanized zones (**Figure 1-3**).

Figure 1-3: Flood prone area in Cooksville Creek watershed

As part of adaptive management, stormwater management has evolved over time in Ontario, from flood control requirements in the 1970s, to water quality and erosion requirements in the 1980s, to water balance requirements in 2012. The cost and complexity of these engineered systems has increased. In light of the current spot light on climate change and aging infrastructure there is growing awareness that stormwater management has become more than just treating a storm event it's also about maintaining stream flows during dry weather periods for wastewater assimilation, fisheries, and water takings. Through the Great Lakes Protection Act, Water Opportunities Act and Redside Dace legislation, stormwater is being recognized as a resource to be treated at source, conveyance and prior to entering waterways.

A robust stormwater management system that meets all environmental and economic goals must include both conventional stormwater management facilities and source based Low Impact Development (LID) practices. Conventional facilities are typically effective at achieving flood control by providing large volumes of stormwater detention. Conventional facilities however lack the ability to provide water balance benefits or reduce the volume of runoff from heavily urbanized areas. As a result they offer little benefits with respect to infiltration and erosion mitigation. LID practices excel where conventional systems fail by allowing for natural hydrologic processes including infiltration and evapotranspiration as close to the source as possible.

LID practices are designed to mitigate the rapidly changing water cycle by mimicking nature within the urban environment. LID strategies strive to allow natural infiltration to occur as close as possible to the original area of rainfall. By engineering terrain, vegetation, and soil features to perform this function, the landscape can retain more of its natural hydrological function (**Figure 1-4**). Although most effective when implemented on a community-wide basis, using LID practices on a smaller scale can also have a positive impact.

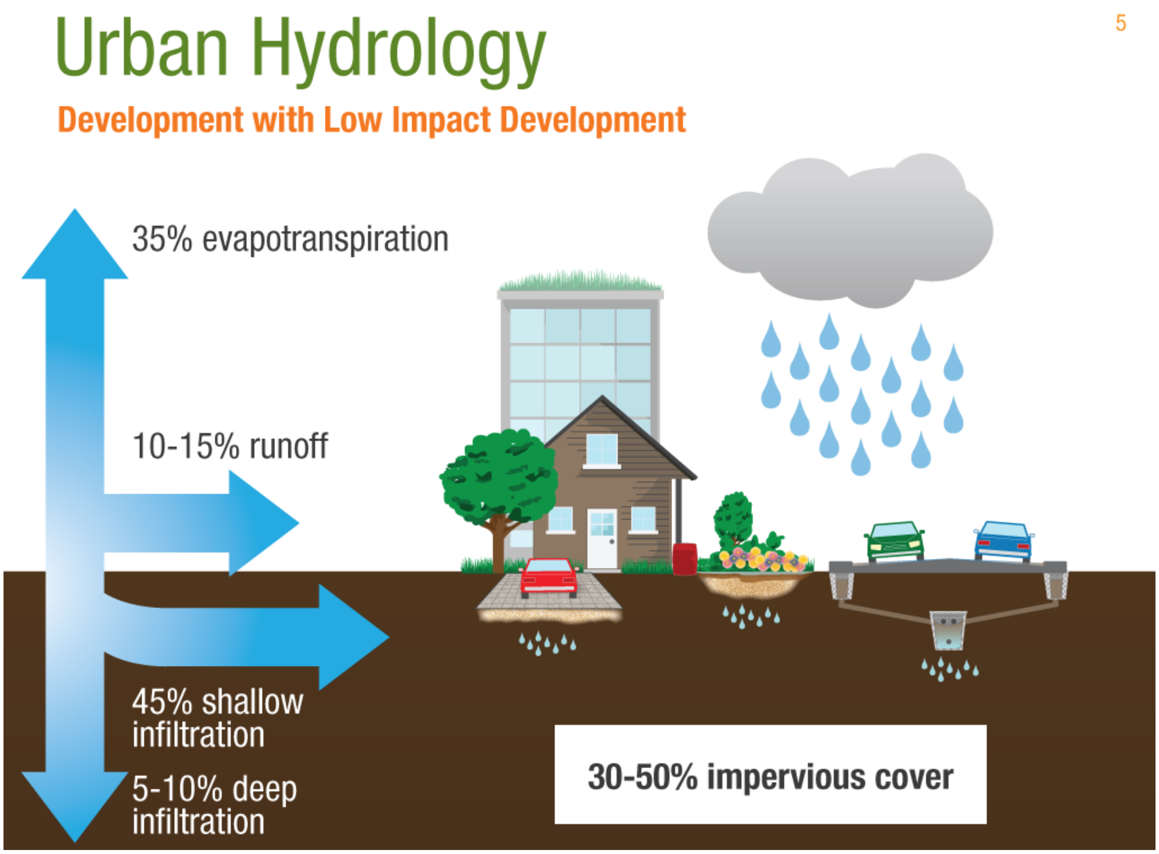


Figure 1-4: Urban water cycle with Low Impact Development stormwater Management - (Adapted from FIRSWG, 1998)

2 UNEXPECTED CONSEQUENCES OF URBAN DEVELOPMENT

As might be expected, there is a linear relationship between the amount of impervious surfaces in a given area and the amount of runoff generated. What is unexpected is what this means in terms of both the volume of water generated and the rate at which it exits the surface. Depending on the degree of impervious cover, the annual volume of storm water runoff can increase to anywhere from 2 to 16 times the predevelopment amount[6]. Impervious surface coverage as low as 10% can destabilize a stream channel, raise water temperatures, and reduce water quality and biodiversity[7].

[6] Schueler, T. 1994. The Importance of Imperviousness. Watershed Protection Techniques 1(3):1'00-111.

[7] Schueler, T. 1995. Site Planning for Urban Stream Protection. Metropolitan WashingtonCouncil of Governments, Washington, DC.

This is consistent with monitoring data from the urbanizing subwatershed of Fletchers' Creek which shows increasing trends in peak flows downstream from developed catchments despite post to pre-development control with conventional SWM facilities such as wet ponds. In fact, the flow of the creek has on average increased by roughly two orders of magnitude despite the adoption of conventional stormwater management (**Figure 2-1**).

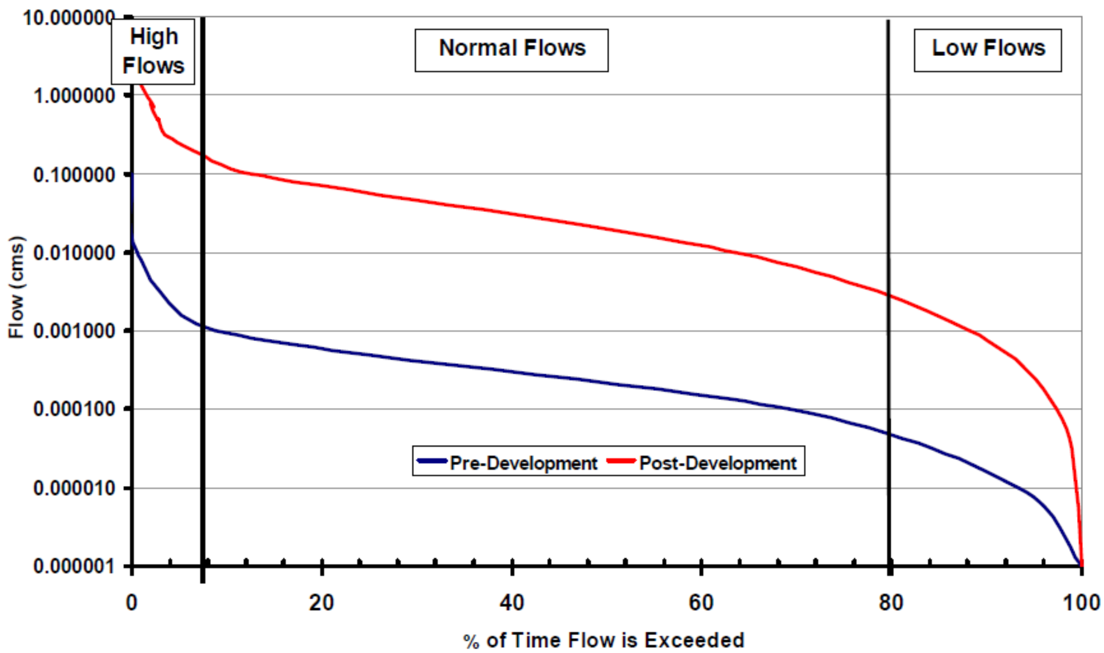


Figure 2-1: Increasing trends in stream flow pre- and post-construction in Fletchers' Creek

The longer duration of higher flows due to increased volume combines with that from downstream tributaries to increase the downstream peaks. As a result, the portions of Fletchers Creek is experiencing extensive bank slumping and erosion (**Figure 2-2**).

Figure 2-2: High stream flow in Fletcher's Creek

In a natural setting, typically 6-9 events per year produce runoff that enters the stream. With LID stormwater management, very little to no runoff is produced during precipitation events less than 25 mm in depth, that is 90% of all precipitation events. What this means is that 69% of all the rain to fall will not produce runoff. In fact, LID sites can prevent runoff for events up to 25 mm in depth (**Figure 2-3**). For rainfall events with a depth greater than 25 mm, in which runoff is produced, it was previously thought that LID would have little effect in mitigating flows. However, monitoring data has shown that there is runoff volume reductions and peak flow reductions even for large storm events.

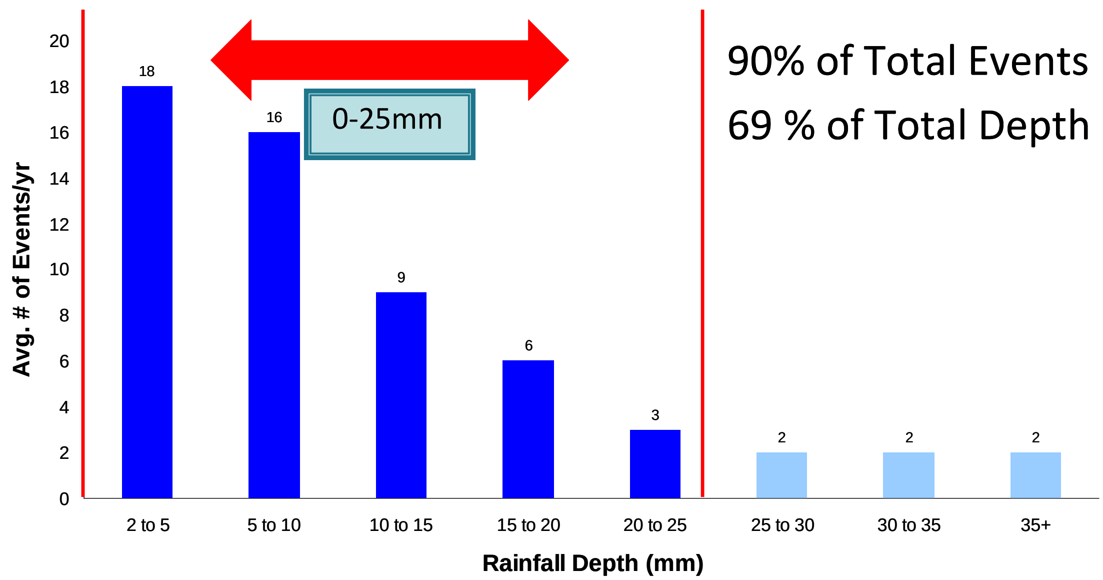


Figure 2-3: Typical Annual Rainfall Frequency Distribution for Toronto Lester B. Pearson 1960-2012

3 CHANGES IN WATER QUALITY

Pollution from storm water runoff can also be a major concern in urban areas. Rainwater washing across streets and sidewalks can pick up spilled oil, detergents, solvents, de-icing salt, pesticides, fertilizer, and bacteria from pet waste. Carried untreated into streams and waterways, these materials become "non-point source pollutants" which can increase water temperature, algae content, impact aquatic habitats, cause beach closures and require additional costly treatment to make the water potable for drinking water systems. Beach closures and reductions in recreational fishing due to pollutant loading from urban stormwater and have resulted in up to $87 million a year in lost revenue to local economies[8].

Figure 3-1: Sediment Plume from Credit River to Lake Ontario (Photo Credit: Aquafor Beech, 1990)

[8] Marbek (submitted to Ontario Ministry of Environment). 2010. Assessing the Economic Value of Protecting the Great Lakes: Rouge River Case Study for Nutrient Reduction and Nearshore Health Protection. http://www.greeninfrastructureontario.org/sites/greeninfrastructureontario.org/files/Final%20Rouge%20Report%20Nov%2030.pdf

During last three decades, Ontario developers and municipalities have constructed end-of-pipe wet facilities (i.e. wet ponds, wetlands and hybrid ponds) as standalone stormwater management facilities to provide water quality control through the removal of total suspended solids. Conventional end-of-pipe wet stormwater management ponds, in which the main treatment mechanism is capture of particulates through settling, are not effective in removing the fine particles that carry most of the nutrients as well as most of the dissolved pollutants and hydrocarbons. The increase in water temperature as result of the increase in impervious surfaces is also a major water quality concern in urban streams. Retention of stormwater in conventional wet ponds allows stormwater to warm up, causing thermal impacts on receiving water bodies. Because temperature plays a central role in the rate and timing of instream biotic and abiotic reactions, such increases have an adverse impact on streams. In some regions, summer stream warming can irreversibly shift a cold-water stream to a cool-water or even warm-water stream, resulting in deleterious effects on salmonids and other temperature-sensitive organisms.

In the Credit River Watershed, the difference in the concentration of total suspended solids (TSS) in an urban stream that was receiving stormwater from upland developments with conventional end-of-pipe wet facilities and a rural stream with only 10 - 20% impervious cover during dry ambient condition is shown in **Figure 3-2**. The comparison demonstrated that there are higher levels of TSS in the stream draining the developed area with conventional stormwater management wet facilities than in the rural area. This is due to the lack of runoff volume control in the stormwater management ponds.

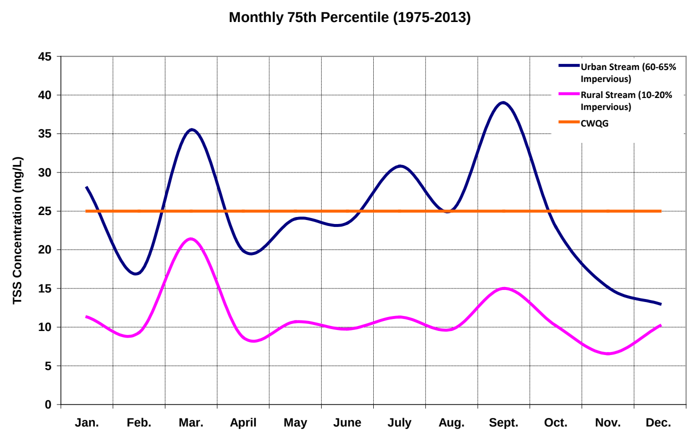


Figure 3-2: Monthly 75th Percentile Total Suspended Solids concentration compared at an urban vs. rural catchment

Note: Different urban/rural streams have unique responses to development. The example graphs how scenarios observed for one rural and one urban watercourse in CVC's jurisdiction.

There is also significant concern about phosphorus loading from urban areas. Phosphorus is one of main pollutants of concern in urban drainage. Phosphorus and other nutrients are transported by runoff in a particulate-bound and dissolved phosphorus form.

The Total Phosphorus (TP) concentration in two monitored streams within CVC's watershed showed similar results to those observed for TSS. Higher phosphorous concentrations were observed in the urban stream that was receiving stormwater from upland developments into a conventional end-of-pipe SWM facility than in the rural stream that had only 10 - 20% impervious cover during the summer months. Peak concentrations were seen in the rural stream during the spring season whereas peak concentrations were seen in the urban stream during the summer season (**Figure 3-3**). This is due to the greater level of impervious surfaces and lack of stormwater volume control in the urban stream. Elevated concentrations of nutrients in the summer season is the major factor contributing to excess algae growth and depressed dissolved oxygen in receiving streams[9].

[9] Aquafor Beech (for Conservation Halton). 2005. LOSAAAC Water Quality Study. Aquafor Beech reference 64353. https://halton.ca/living_in_halton/water_wastewater/water_quality_protection/lake_ontario/LOSAAAC/

Currently there is a significant concern about phosphorus loading from urban areas. Phosphorus is considered as one of main pollutants of concern in urban drainage. Phosphorus and other nutrients are transported by runoff in a particulate-bound and dissolved phosphorus form.

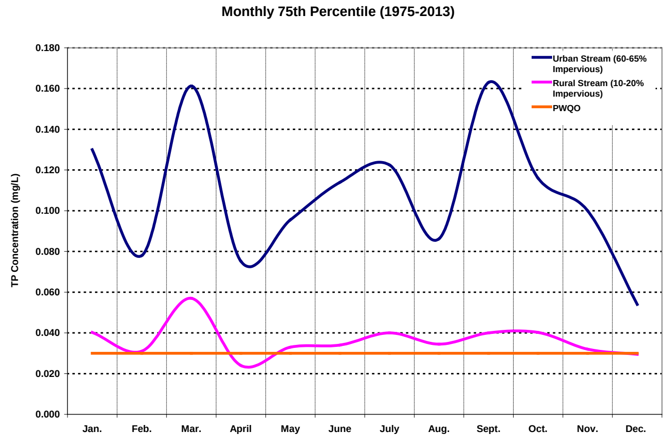


Figure 3-3: Monthly 75th Percentile Total Phosphorus concentration compared at an urban vs. rural catchment

New York State SWM Design Manual also states that "Based on the best available data, it has been observed that particles less than 10 μm tend to have substantially higher associated phosphorus concentrations than larger particle sizes". This raises concerns with respect to the ability of wet ponds to remove particulate phosphorus as they are not efficient in removing particles less than 10 μm[10]. Moreover, treatment mechanisms focused on capture of particulates does not address dissolved phosphorus removal. This is consistent with the *2003 MOE Stormwater Design Guidelines*, which state that while end-of-pipe facilities are typically designed to remove 60-80% suspended solids, the typical removal efficiency for total phosphorus is 40-50%.

Section 4.4 of the *2003 MOE Stormwater Design Guidelines* also recognizes that the use of stormwater ponds for water quantity and quality control can impair receiving stream habitat because of the heating of the discharge water. Because a municipality may have hundreds of wet stormwater management facilities within a single watershed, the cumulative impacts on aquatic systems can be significant.

Figure 3-4: High TSS from urban runoff in Springbrook Creek habitat of Redside Dace

In streams containing Redside Dace, Ministry of Natural Resources requires that there be no storm runoff from rainfall events in the range of 5 to 15 mm, considering the recommendations of the subwatershed plans and soil permeability[11]. In such circumstances, low impact development strategies to promote infiltration and stormwater reuse should be utilized to match post development water balance with the pre-development condition.

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[10] Greb, S. and Bannerman, R. 1997. Influence of particle size on wet pond effectiveness. Water Environment Research, 69 (6): 1134-1138.

Ministry of Natural Resources (MNR). 2011. DRAFT Guidance for Development Activities in Redside Dace Protected Habitat. Ontario Ministry of Natural Resources, Peterborough, Ontario. ii+42 pp [11]

4 RESOURCE INFORMATION

Literature reviews show that LID practices mitigate the impacts of urbanization by mimicking pre-development hydrology. CVC/TRCA's Low Impact Development Stormwater Management Planning and Design Guide provides planning and design guidance on a wide range of stormwater management practices such as bioretention, disconnection of downspouts, rain harvesting, swales, permeable pavement, and green roofs.

Prevention of urban runoff is an effective means to achieve a broad range of stormwater management objectives such as maintaining pre-development runoff volume, frequency and duration for frequent storm events, reducing runoff temperature, reducing the concentration of TSS and reducing the loading of phosphorus into surface waters. Reducing imperviousness and disconnection of impervious areas can be achieved through alternative design standards for road widths, road right of ways, minimum numbers of parking lot, varied front and rear lots, the use of pervious materials and the use of source controls as discussed in the above document.

For detailed information on preventative and mitigation measures to address thermal impacts of urban developments, refer to CVC's Study Report: Thermal Impacts of Urbanization including Preventative and Mitigation Techniques and CVC/TRCA Low Impact Development Stormwater Management Planning and Design Guide.