CREDIT VALLEY CONSERVATION

Elm Drive

Low Impact Development Infrastructure Performance and Risk Assessment

May 2016

Technical Report

Road Right-of-Way Retrofit

ELM DRIVE, CITY OF MISSISSAUGA

LOW IMPACT DEVELOPMENT INFRASTRUCTURE PERFORMANCE AND RISK ASSESSMENT

TECHNICAL REPORT

MONITORING RESULTS (2011 – 2015)

CREDIT VALLEY CONSERVATION

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ASCE	American Society of Civil Engineers
ASTM	American Society for Testing and Materials
BMP	best management practice
BMPDB	International Stormwater Best Management Practices Database
cm	centimetre
CCME	Canadian Council of Ministers of the Environment
Cu	copper
CVC	Credit Valley Conservation
EC	Environment Canada
EMC	event mean concentration
g	Gram
GTA	Greater Toronto Area
ha	hectare
hr	Hour
HSG	hydrologic soil group
kg	kilogram
IRPA	infrastructure performance and risk assessment
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
MEDEI	Ministry of Economic Development, Employment and Infrastructure
mg	milligram
µg/L	micrograms per litre
min	Minute
mm	Millimetre
MTO	Ontario Ministry of Transportation
N	Nitrogen
NSQD	National Stormwater Quality Database
NO_2 and NO_3	nitrite and nitrate
MOE or MOECC	Ontario Ministry of the Environment and Climate Change

PO_4	orthophosphate
P	Phosphorus
PAH	polycyclic aromatic hydrocarbon
PDSB	Peel District School Board
PoC	parameters of concern
PSD	particle size distribution
PVC	polyvinyl chloride
PWQO	Provincial Water Quality Objective
RL	reporting limit
s	Second
SWMM	Stormwater Management Model (EPA SWMM)
TDS	total dissolved solids
TMIG	The Municipal Infrastructure Group
TKN	total Kjeldahl nitrogen
TN	total nitrogen
TP	total phosphorus
TSS	total suspended solids
UNHSC	University of New Hampshire Stormwater Center
U.S. EPA	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 per cent 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.

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 over 25 public and private-sector organizations to implement a number of innovative stormwater management retrofits on both public and private properties. Elm Drive, in downtown Mississauga, is the first low impact development road reconstruction project of its kind in Ontario.

Low impact development (LID), 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.

Streets, sidewalks and driveways contribute 65-75 per cent of total loadings of suspended solids, total phosphorus, and metals (Bannerman, et. al., 1992). Given that streets are the largest urban contributor and are municipally owned land, they provide a great opportunity to control runoff. LID retrofits implemented as part of road reconstruction projects have also been found to save on average 25 per cent in comparison to traditional practices when land costs are considered (USEPA, 2007). For more information on CVC's LID sites and Infrastructure Performance and Risk Assessment project, visit www.bealeader.ca

The Elm Drive Retrofit demonstrates the use of LID within the municipal right-of-way along a mixed use street. CVC is conducting comprehensive performance and risk assessment at this site to evaluate a combination of permeable pavement parking lay-bys followed by a series of linear bioretention systems to reduce runoff volume and remove pollutants before discharge to the municipal storm sewer. The construction of the Elm Drive retrofit was completed in May 2011. Flow monitoring began in August 2011 and water quality monitoring began in June 2012. This report summarizes the results of the monitoring prior to September 2015.

Fifteen events with depths between 33 and 62 mm, with return intervals of 2 years to more than 10 years, had peak flows reduced by 66 to 95 per cent. Substantial runoff volume reductions (about 59 per cent) for events larger than 30 mm contributed to the reduced peak flows. At least 24 mm was retained by the LID systems for these fifteen large events. These findings support the ability of LID systems to provide resilience under intense rainfall events, contribute to flood damage avoidance and mitigate stream erosion.

Events up to 25 mm in magnitude occur much more frequently and contribute to a large proportion of the average annual precipitation in southern Ontario. Events in this size range are also responsible for transporting a large proportion of the annual contaminant load delivered to receiving waters. Therefore, their management is particularly important for water balance and water quality objectives. The volume reduction achieved for events up to 25 mm in magnitude was 93 per cent. The retrofit achieved 88 per cent load reduction of total suspended solids (TSS), exceeding the water quality criteria of 80 per cent

TSS removal. More than 85 per cent load removal was achieved for all parameters except nitrate, for which 60 per cent load removal was achieved.

This performance data suggests that widespread adoption of LID would yield significant benefits to receiving streams as well as the Great Lakes. Results from Elm Drive 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. They are providing the local, long-term performance data needed to conduct the integrated life-cycle analysis required for asset management.

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. 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 per cent discount rate, was estimated at $0.8 billion dollars (Atkins, 2015). If green infrastructure was also 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 total suspended solids (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 in Ontario

The Ministry of Economic Development, Employment and Infrastructure (MEDEI) (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 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.

The guiding objectives for all CVC stormwater monitoring projects can be found within the *CVC Stormwater Management Monitoring Strategy*.

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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 the promotion of voluntary efforts. 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 Elm Drive LID Retrofit

Nearly 60 per cent of Canadians believe that municipalities are upgrading municipal stormwater systems to manage more extreme events associated with climate change (RBC, 2013). However, the reality is that investment continues to lag behind the need to prevent deterioration of existing infrastructure. For example, the 2016 Canadian Infrastructure Report Card reported that the investment rate for linear stormwater infrastructure is 0.3 per cent, compared to a target of between 1.0 and 1.3 per cent, and the investment rate for other stormwater infrastructure is 1.3 per cent, compared to a target of between 1.7and 2.0 per cent. Further, within areas that are already developed, there is limited space to increase the storage capacity of the stormwater management system. Municipally owned land such as road allowances and public spaces such as schools provide opportunities to incorporate green infrastructure and demonstrate their performance and cost-effectiveness, as well as, educate the public on stormwater management.

To showcase innovative stormwater technologies to the public and private sector, the City of Mississauga partnered with the Peel District School Board (PDSB) and CVC to develop a green street pilot project for Elm Drive West. This demonstration site is located approximately two blocks south of Square One, a high-volume shopping centre in the heart of Mississauga. Elm Drive is a mixed-use street with residential homes along its east side between Joan Drive and Kariya Drive and the PDSB's Adult Education Centre along the west side. **Figure 1-1** shows the location of the Elm Drive site in the context of the Credit Valley jurisdiction.

Toronto alone has enough roads that if put end to end would extend from Vancouver to Halifax and back (City of Toronto, 2015).

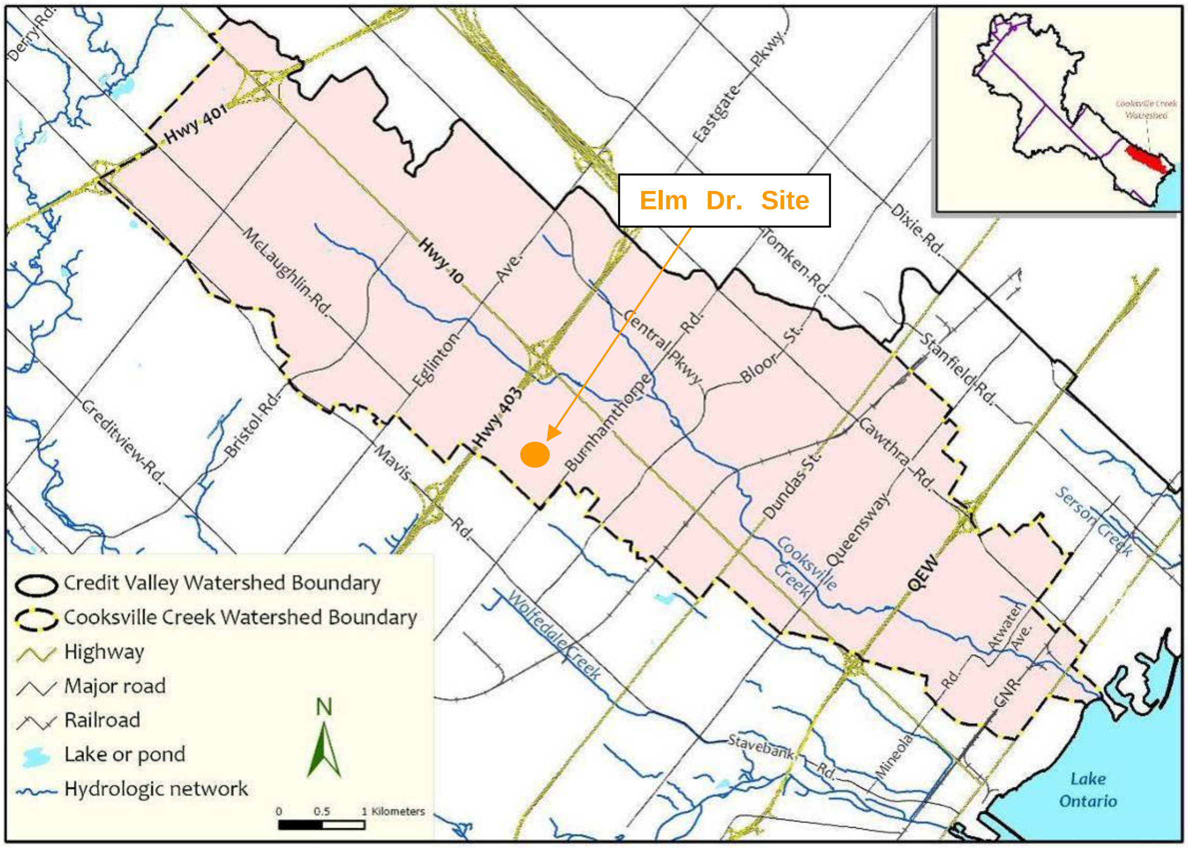


Figure 1-1: Elm Drive stormwater management site location in the Cooksville Creek sub-watershed of the Credit Valley Watershed.

Some of the Key Drivers for the Implementation LID along Elm Drive

- Without the passion, commitment, and support of Councillors Pat Mullin, Jim Tovey, Nando Iannicca and Peel School Board trustees including Janet McDougald, this project would not have been possible. Their leadership and dedication have made this site the first of its kind in Canada.
- It was designed to provide water quality treatment, in keeping with the recommendations from the City of Mississauga's Water Quality Strategy and Green Development Standards.
- It provides an opportunity to partner with the Peel District School Board to improve traffic/parking congestion, coordinate maintenance and performance monitoring to assess feasibility of implementing these techniques city-wide.
- It also provides an opportunity to showcase innovative stormwater technologies to private landowners in light of the City's recent Stormwater Rate Initiative.
- It supports the vision, goals, and objectives of Mississauga's strategic plan, Our Future Mississauga, by demonstrating that the health and attractiveness of Mississauga's communities, natural environments and drinking water supply would be improved by encouraging and supporting alternative stormwater management strategies.

2 LID MONITORING OBJECTIVES

Working with project partners and stakeholders, CVC has defined 19 objectives for CVC's overall 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 Stakeholders at the monitoring objectives meeting

The stakeholder group identified the following objectives for the program:

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.

The five key objectives in bold print were used as the basis of the monitoring program at Elm Drive. Given that a treatment train of permeable pavement and bioretention cells is used and the native soils at Elm Drive are clay, this site can contribute to objectives 1 and 4. This report focusses on findings related to objectives 1, 4 and 5. Long-term monitoring, and sustained funding to support it, will allow for objectives related to long-term performance, maintenance and life cycle costs to be evaluated in the future. To assess objectives, CVC has developed comprehensive meteorological, hydrologic and water quality assessment protocols (see **Appendix B**).

3 ELM DRIVE LID SITE DESIGN

The Elm Drive Project incorporates green infrastructure including permeable pavement and bioretention cells/planters which filter and store stormwater from impervious surfaces. Prior to the LID retrofit, this site drained into Cooksville Creek with little treatment, and runoff ultimately flowed to Lake Ontario. **Figure 3-1** and **Figure 3-2** demonstrate the drainage on the site pre-construction and post-construction, respectively.

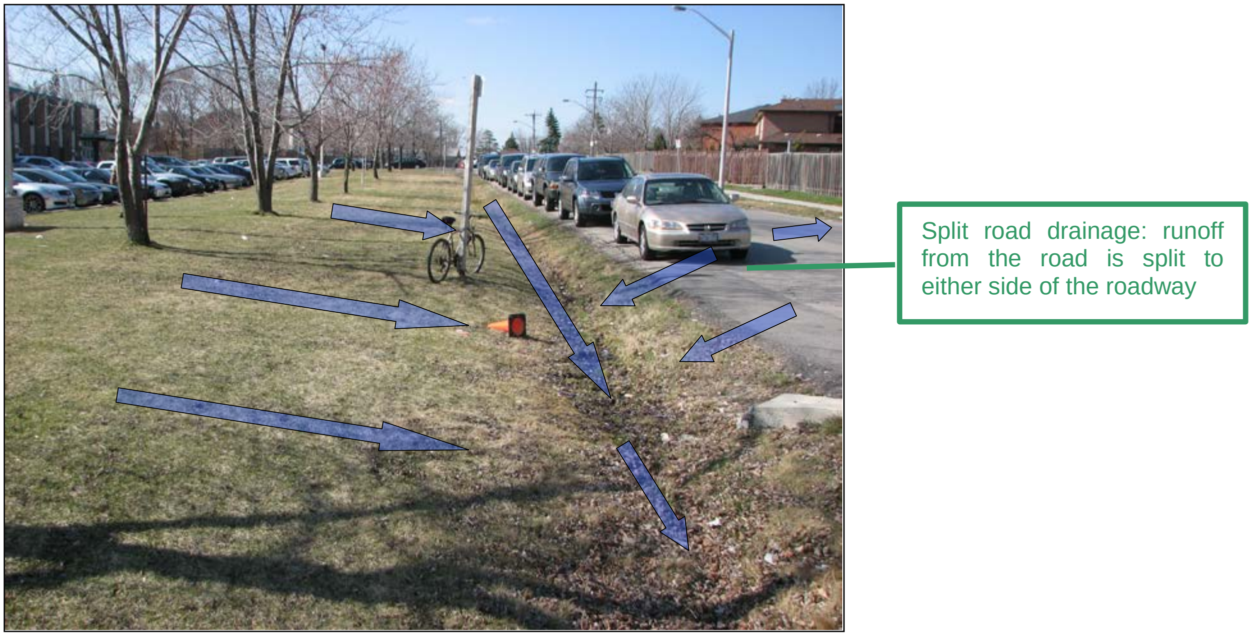


Figure 3-1: Before retrofit; drainage on Elm Drive

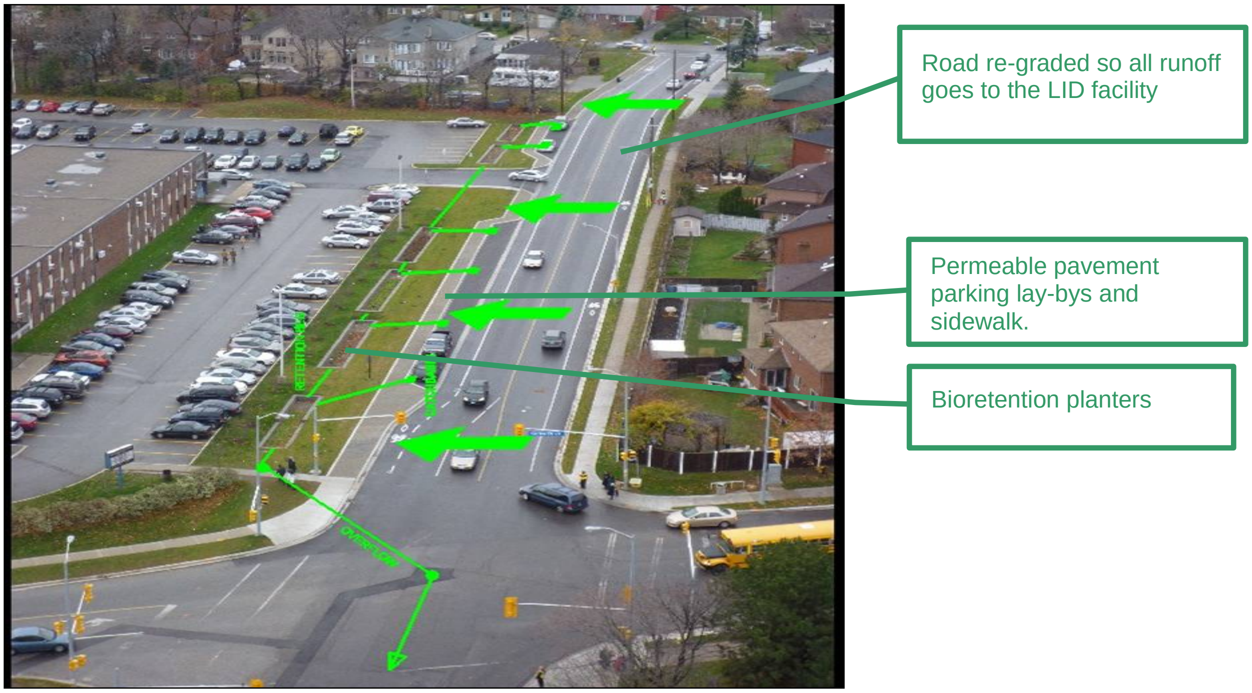


Figure 3-2: After retrofit; drainage on Elm Drive

Prior to construction, drainage of Elm Drive was divided at the road centreline and routed to each side of the road. The grass swales provided limited treatment for runoff before it entered the municipal sewer system. Post-construction, runoff from all lanes of the road flows towards the permeable pavement lay-bys with overflow going to the bioretention features. Runoff which is not retained by the LID systems through infiltration or evapotranspiration discharges to the municipal sewer. The estimated total drainage area for the site is 0.646 hectares (ha).

As **Figure 3-3** illustrates, two sets of bioretention cells located along Elm Drive West receive runoff from the street, sidewalk and some landscaped areas. The western set (Set 1 in the figure) consists of two individual cells (Cells 1 and 2), which have a tributary area of 0.280 ha. The eastern set (Set 2 in the figure) consists of four individual cells (Cells 3 to 6), which have a tributary area of 0.366 ha. The permeable pavement lay-bys and sidewalk receive runoff from the street. Catch basin sumps collect the runoff before it is conveyed to the bioretention cells via underground pipes. The bioretention filter mix comprises sand, fines, and organic matter in the proportions indicated in **Table 3-1**. All bioretention cells are connected by underdrains, which drain to the monitoring manhole (ED-1) downstream of the system.

Several boreholes were drilled to evaluate the subsurface soil conditions at Elm Drive. The borehole logs illustrate the observed layers of topsoil, clayey silt, and dense silt till. Percolation tests conducted adjacent to the boreholes showed that the percolation rate was very low when the subsurface soil was saturated. Refer to **Appendix F** for the geotechnical report.

The Elm Drive Project was intended to provide water quality benefits while improving runoff quantity control. During relatively small and frequently occurring runoff events (e.g., less than 25 mm), stormwater is expected to infiltrate into the bioretention filter media. During high intensity events, surface ponding within the bioretention cells can occur. A portion of the runoff volume from large magnitude events can still pass through the filter media and receive treatment. The storage also provides a degree of attenuation for high flows. Detention at this retrofit site was limited by space constraints. New development projects with similar area and land use would typically be larger and therefore capable of more detention.

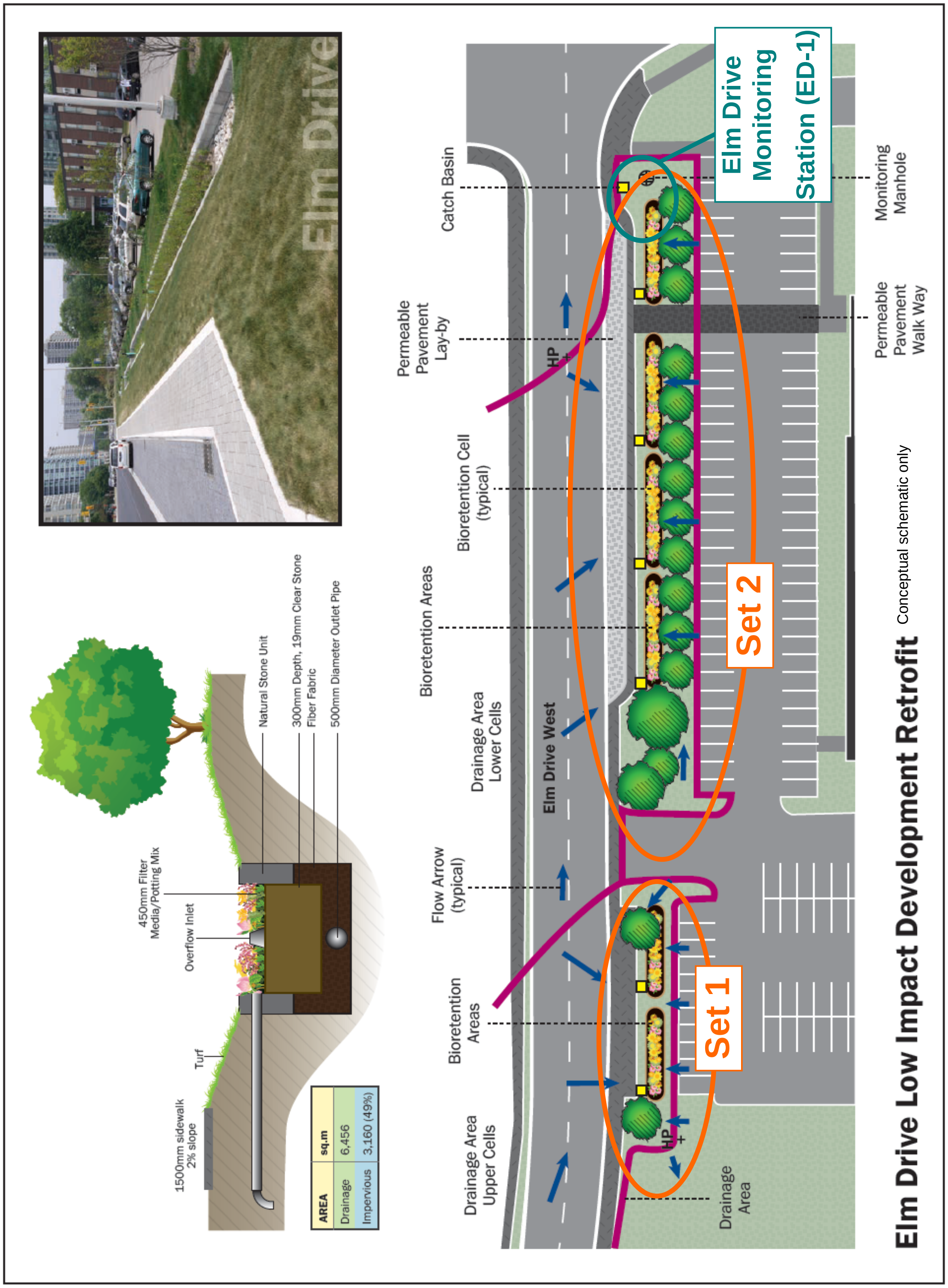


Figure 3-3: Elm Drive LID assessment site with catchment area boundaries

Table 3-1 summarizes sizing and other design information for the bioretention cells. The required storage is based on post-construction updates of total and impervious portion of drainage area.

Table 3-1 Elm Drive bioretention design information

Design sizing	Set 1 (Western)	Set 2 (Eastern)	Total site
# of bioretention cells	2	4	6
Drainage area	0.280 ha	0.366 ha	0.646 ha
% Impervious	41%	60%	51%
Water quality storage volume requirement*	26.5 m^3/ha	31.7 m^3/ha	29.2 m^3/ha
Total water quality storage volume required	7.4 m^3	11.6 m^3	19.0 m^3
Surface area of cells	43.9 m^2	101.2 m^2	145.1 m^2
Retention storage volume**	12 m^3	28 m^3	40 m^3
Detention storage volume**	30 m^3	70 m^3	100 m^3
Bioretention filter mix specification	▪ Depth 450 mm ▪ Sand (2.0 to 0.050 mm Ø) 85-88% (by weight) ▪ Fines (<0.05 mm Ø) 8-12% (by weight) ▪ Organic Matter 3-5% (by weight)		

* Table 3.2 of the 2003 Stormwater Management Planning and Design Manual.

**Retention storage volume is estimated as void space below the underdrain. Additional detention (temporary) storage above the underdrain (void spaces and on the surface of the cells) provides additional storage capacity.

Table 3-2 provides the predicted performance of the Elm Drive retrofit site. The predicted performance was obtained from the July 6, 2010 memo regarding SWM Analysis prepared by The Municipal Infrastructure Group. **Table 3-2** also provides the stormwater management criteria for new developments and the estimated performance of the retrofit condition relative to the pre-development condition. While green infrastructure is most effective for runoff volume and water quality control, it is also of interest to evaluate the extent to which it can help to attenuate peak flow rates.

Table 3-2 Predicted performance of Elm Drive retrofit (adapted from TMIG, 2010)

Stormwater management design criteria	Elm Drive retrofit design estimations*		CVC stormwater management criteria for new developments
Flood control (peak flow)	Peak flow reduction (relative to pre-retrofit condition): 2 yr (33 mm) - 37% 5 yr (45 mm) - 27% 10 yr (55 mm) - 8% 25 yr (64 mm) - 5% 50 yr (71 mm) - 10% 100 yr (79 mm) - 13%	Peak flow increase (relative to pre-development condition): 2 yr (33 mm) - 84% 5 yr (45 mm) - 63% 10 yr (55 mm) - 82% 25 yr (64 mm) - 73% 50 yr (71 mm) - 58% 100 yr (79 mm) - 45%	Post to pre-control of peak flows for the 2 to 100 year design storms
Erosion control (runoff volume)	Runoff volume reduction (relative to pre-retrofit conditions): 2 yr (33 mm) - 29% 5 yr (45 mm) - 19% 10 yr (55 mm) - 13% 25 yr (64 mm) - 11% 50 yr (71 mm) - 9% 100 yr (79 mm) - 8% (With associated erosion control)	Runoff volume increase (relative to pre-development conditions): 2 yr (33 mm) - 12% 5 yr (45 mm) - 17% 10 yr (55 mm) - 18% 25 yr (64 mm) - 17% 50 yr (71 mm) - 16% 100 yr (79 mm) - 15%	At a minimum detain 5 mm. For sites with stormwater management ponds, detain 25 mm for 48 hrs. Note: Detention (without retention) helps to manage peak flows but does not reduce runoff volume
Water quality	Enhanced level of treatment (80% TSS removal) Note: Based on providing more storage than indicated by Table 3.2 of the 2003 Stormwater Management Planning and Design Manual.		Enhanced level of treatment (80% TSS removal)

* Source: July 6, 2010 memo re: SWM Analysis prepared by The Municipal Infrastructure Group (TMIG 2010). The depth for each return period is based on the four-hour Chicago storm event.

4 MONITORING RESULTS AND INTERPRETATIONS

This section provides results from the analysis of monitoring data collected from August 2011 through September 2015. The monitoring program at Elm Drive collects data including precipitation, flow, air and water temperature, and water quality of the outflow from the treatment system. **Table 4-1** summarizes the monitoring locations and equipment at Elm Drive. Details on the monitoring protocols and data management and analysis for Elm Drive can be found in **Appendices B**, **C** and **D**, respectively.

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

Measurement type	Monitoring equipment	Location / description
Flow	Compound weir by Thompson Flow Investigations & ISCO 4150 Flow Logger (water level meter)	Manhole downstream of bioretention
Rainfall depth and intensity	Hydrological Services TB3 Tipping Bucket Rain Gauge	Roof of Adult Education Centre
Water quality sampling	ISCO 6712 Automatic Sampler	Manhole downstream of bioretention
Temperature	HOBO UA-002-64K	Catch basin upstream of bioretention; manhole downstream of bioretention

Note: Find specific protocols for each measurement type in **Appendix A.**

4.1 Precipitation

Precipitation at Elm Drive (**Figure 4-1**) has been monitored continuously since mid-July 2011 with a heated tipping-bucket rain gauge installed on the roof of the PDSB building. This data includes the precipitation amount and how its intensity varies during an event. Additional gauges maintained by the City of Mississauga and CVC are used as a check on the site data and in the event of any gaps in the data from the primary gauge. 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. Regional climate norms provide support in characterizing the events to be expected at Elm Drive and the distribution in southern Ontario but should not be relied upon for determining site hydrology.

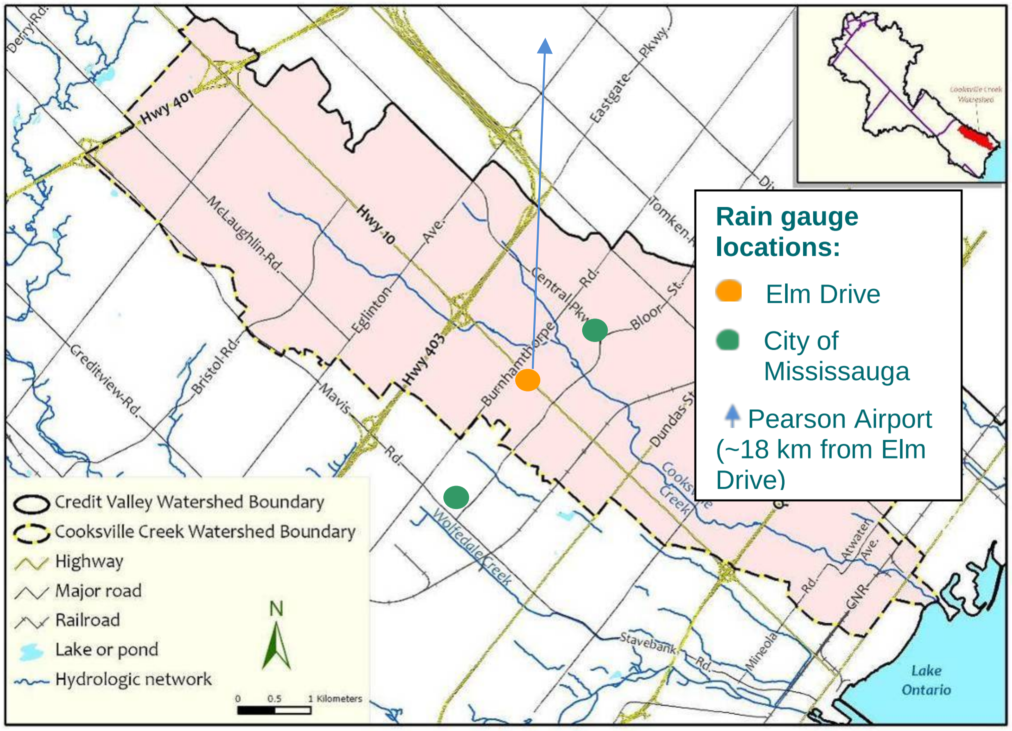


Figure 4-1: Selected rain gauges in reference to Elm Drive

Table 4-2 compares the monthly and annual precipitation measured at Toronto Pearson International Airport to the precipitation recorded at Elm Drive from 2011 to September 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 at Elm Drive was 709, 1048, and 757 mm, respectively. In 2012, the Elm Drive annual precipitation values were 11 per cent lower than the long-term average at Toronto Pearson International Airport. For 2013, the Elm Drive precipitation was 32 per cent higher than the annual average at Toronto Pearson International Airport.

Based on the long-term average precipitation at the Airport, the months of May through September are typically the rainiest months, each exceeding 70 mm of precipitation and 9 per cent of the annual precipitation. Precipitation recorded at Elm Drive generally follows this same trend; however, Elm Drive monthly precipitation totals for October 2012, July and February 2013, and June 2015 are more than double the monthly averages reported at the Airport.

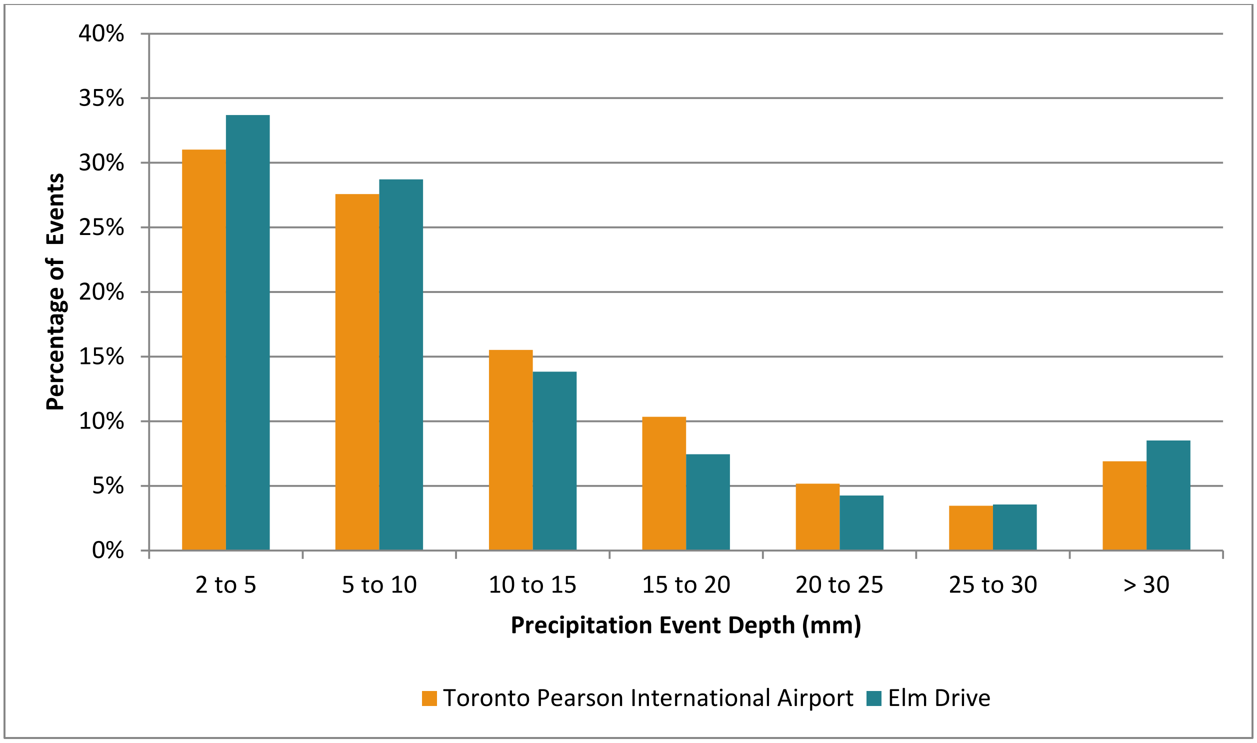
Understanding the relative contributions of events of different sizes to annual rainfall is important for interpreting performance results. Precipitation events are defined as periods of precipitation with a depth of 2 mm or greater. **Figure 4-2** illustrates the typical annual rainfall distribution for the Airport weather station between 1960 and 2012 and the actual number of precipitation events that were recorded at Elm Drive during the monitoring period (2011-2015). The comparison suggests that the frequency of events of various sizes at Elm Drive were similar to the long-term regional frequency of occurrence (**Figure 4-3**). In this chart, hourly weather records from 1950-2005 have been analyzed with WQ-COSM software. This software is designed for determining and maximizing the 'water quality capture volume' for a BMP based on local historical rainfall data. This volume is used to adequately design and size BMPs for improved water quality and quantity control based on historical rainfall.

At Elm Drive, these events accounted for approximately 88 per cent of all precipitation events which compares well with the long-term average for the airport (90 per cent); although during the study period these events contributed only 59 per cent 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.

Table 4-2: Monthly precipitation summary for Elm Drive 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	**792.7**
Elm Drive													
2011	N/A	N/A	N/A	N/A	N/A	N/A	N/A	100.8	99.8	114.4	86.2	53.4	**N/A**
2012	43.2	22.0	20.0	39.0	47.6	78.0	81.4	71.2	106.6	131.2	12.4	56.6	**709.2**
2013[1]	72.2	108	17.8	108.8	77.0	107.8	216.2[1]	76.8	76.4	82.2	36.4	68.2	**1047.8**
2014	79.2	54.6	23.2	97.8	64.8	48.0	95.8	40.6	111.0	66.8	42.4	33.2	**757.4**
2015	26.6	9.4	15.0	95.2	79.0	153.2	42.0	74.4	76.0	N/A	N/A	N/A	**N/A**

[1] Includes July 8, 2013 precipitation event of 100 mm in the first 2 hours of the event (105 mm over 20 hours for the total event).



Note: Includes July 8, 2013 event.

Figure 4-2 Rainfall frequency distribution graph between Environment Canada Toronto Pearson International Airport station (1960-2012) and Elm Drive (August 2011-September 2015)

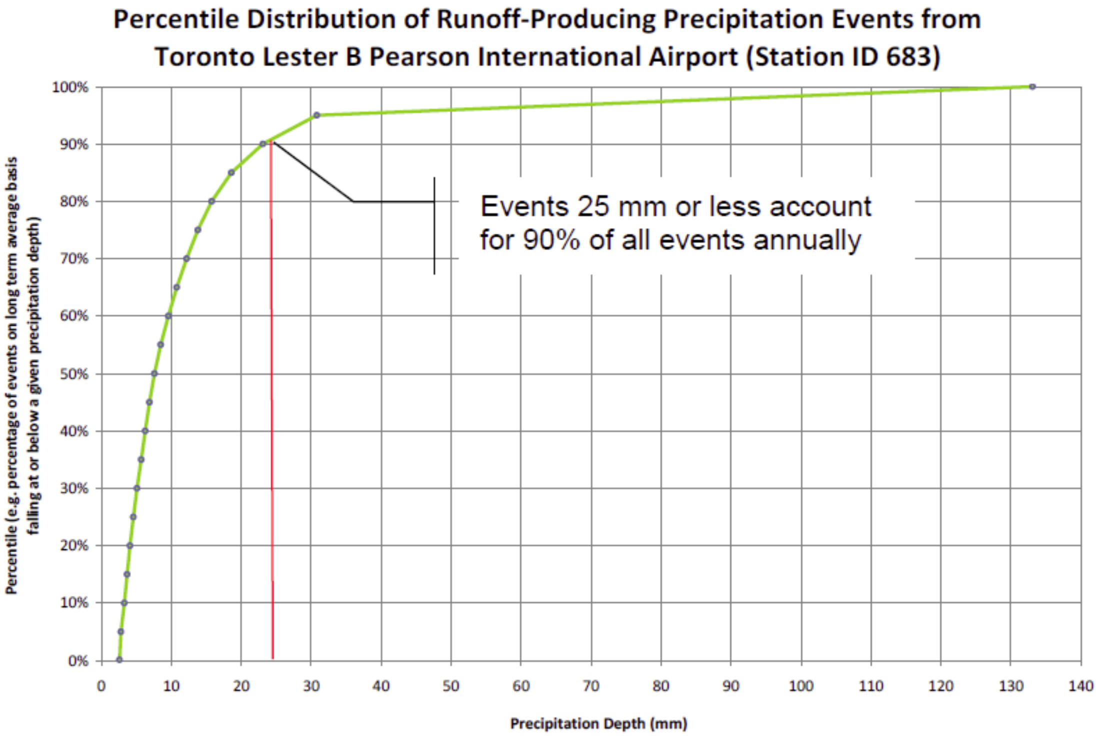


Figure 4-3 Event size related to the frequency of occurrence at Environment Canada Toronto Pearson International Airport station using hourly weather records from 1950-2005

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 4-4**. 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 4-5 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.

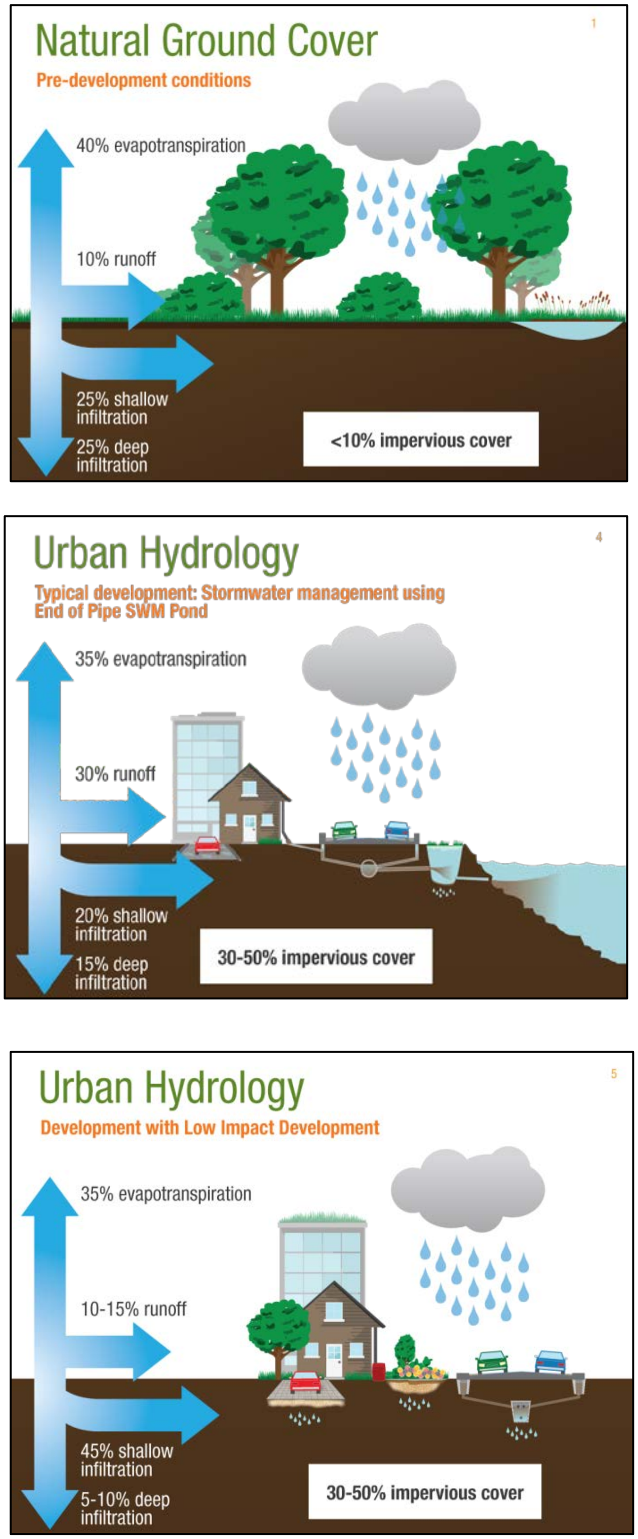


Figure 4-4 Urban water cycle with stormwater management ponds and LID (adapted from FISRWG, 1998)

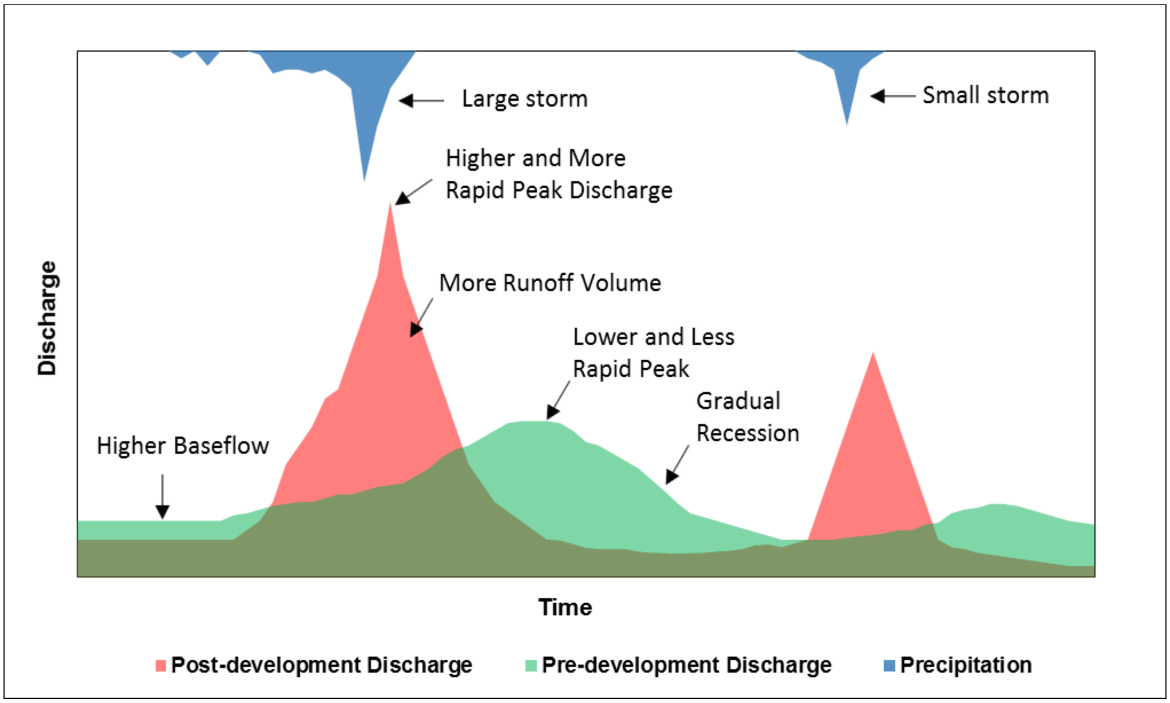


Figure 4-5 Changes in stream flow hydrograph as a result of urbanization (adapted from Schueler, 1987)

4.2.1 Elm Drive Hydrology

Inflows were not measured at Elm Drive but rather estimated using the Simple Method (Schueler, 1987). The site receives inflows as sheet flow and interflow (from permeable pavement sidewalks and lay-bys) which make it difficult to measure influent. The Simple Method transforms rainfall depth into flow and volume based on area and impervious cover (NH DES, 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.”

Effluent flow is measured downstream of the treatment train in a monitoring manhole using a weir and a pressure transducer. Outflow was measured continuously and reported at 10 minute 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 events (>25 mm) 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.

Table 4-3 presents the hydrologic summary for 283 precipitation events (larger than 2 mm), plus two melt events that did not have any simultaneous precipitation, monitored between August 2011 and September 2015.

Table 4-3 ED-1 Event precipitation, flow and volume statistics (August 2011 to September 2015)

Statistic	Antecedent dry period (days)	Event duration (hours)	Peak precipitation intensity (mm/hr)	Total precipitation (mm)	Peak effluent flow (L/s)	Estimated influent volume (L)	Measured effluent volume (L)	Estimated volume reduction (%)
Count	285	285	283	283	61	283	285	283
Mean	2.6	10.4	13.3	11.9	3.58	39.5	7.7	92.4
Median	1.6	6.8	7.2	7.8	1.44	25.6	0	100
25th percentile	0.6	3.5	3.6	4	0.62	13.1	0	100
75th percentile	4.0	13.5	15.6	14.1	3.00	46.3	0	100

4.2.2 Hydrologic Response to Selected Events

Hydrographs for several events monitored at Elm Drive are illustrated in **Figure 4-6** to **Figure 4-8.** The June 7, 2015 event was large (33.4 mm) with three distinct periods of high magnitude, high intensity precipitation. Visual examination of the graph shows that the hydrograph peaks lag 20 to 40 minutes behind the associated peak in precipitation intensity. The overall peak to peak lag for this event was 6.8 hours; the largest peak in the outflow occurred after the third period of intense rainfall, or 6.8 hours after the peak rainfall intensity for the event which occurred in the first period of intense rainfall.

The June 27, 2015 event was a very large (62 mm) event with relatively steady rainfall over almost two days. Once outflow began to be generated, local hydrograph peaks lagged peaks in precipitation intensity by 30 to 50 minutes. The largest outflow for the event occurred immediately (0.67 hours) following the most intense precipitation period recorded for the event.

The August 10, 2015 event was also large (31 mm) with most of the rain (27 mm) falling in the first three hours. Similar to the June 27 event, no flow was generated until well into the event, after more than 20 mm of rainfall.

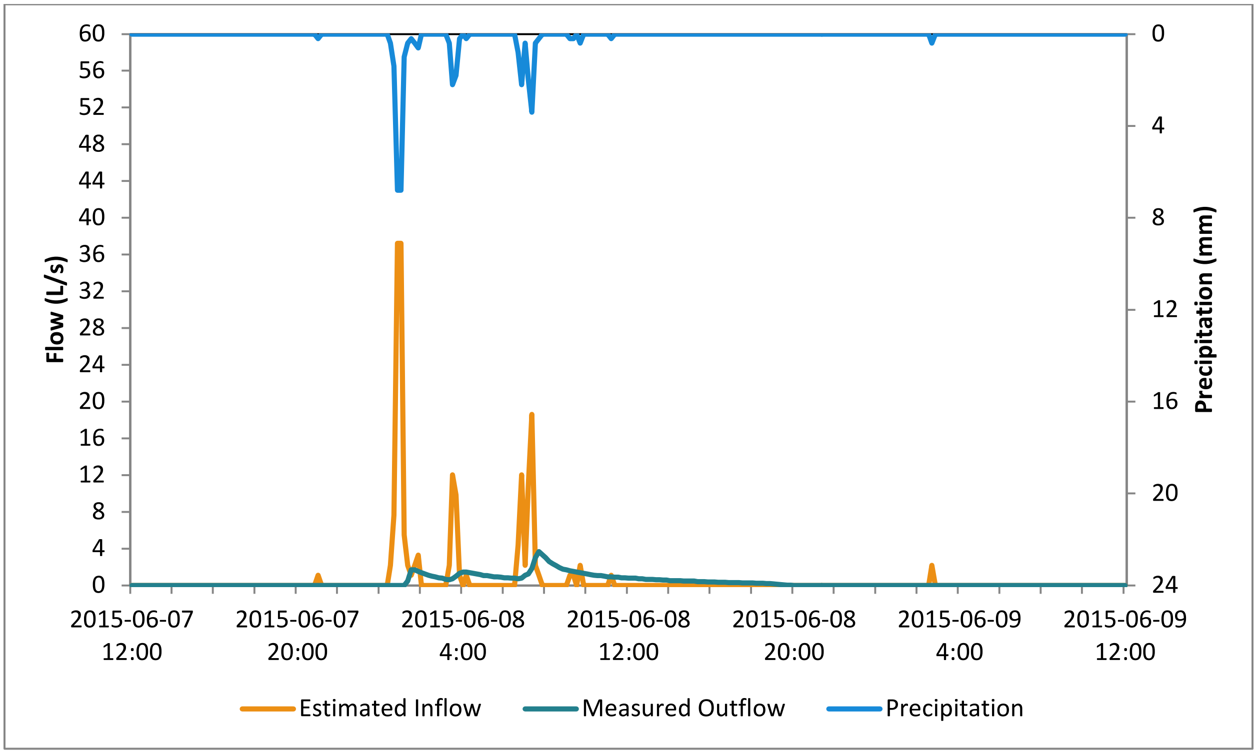


Figure 4-6 Hydrograph for June 7, 2015 (33.4 mm)

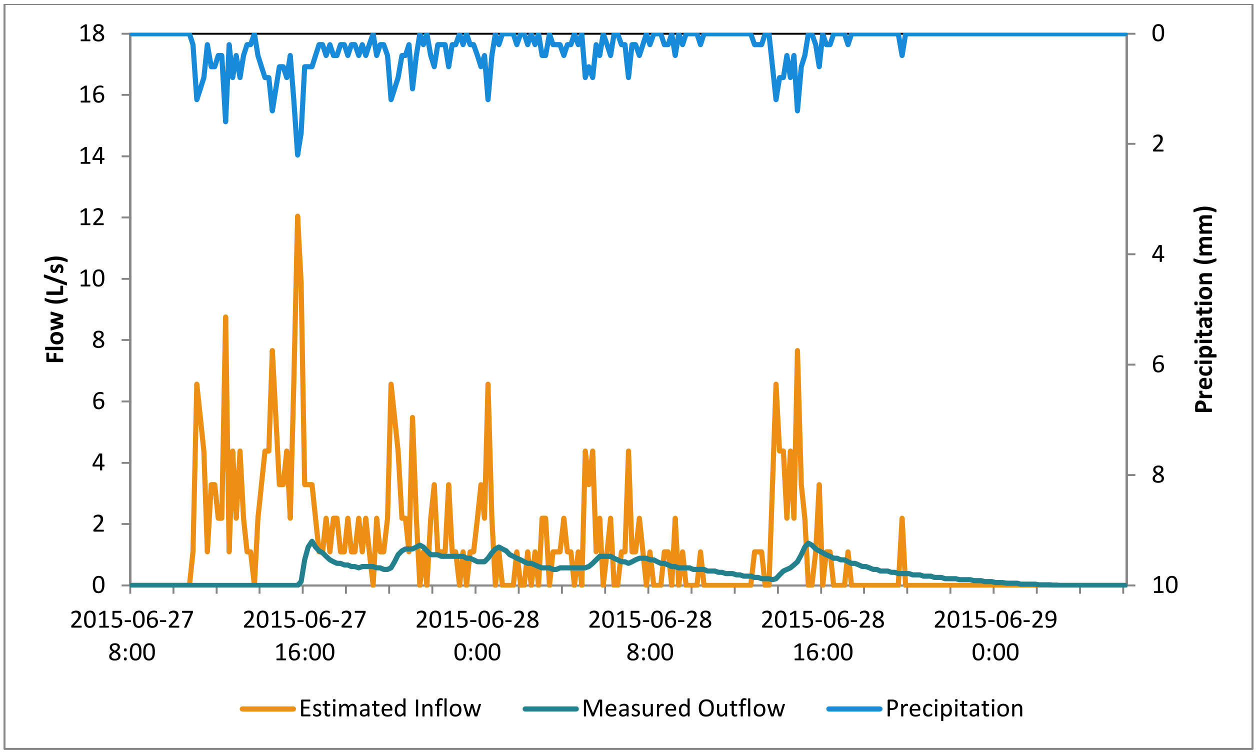


Figure 4-7 Hydrograph for June 27 2015 (62 mm)

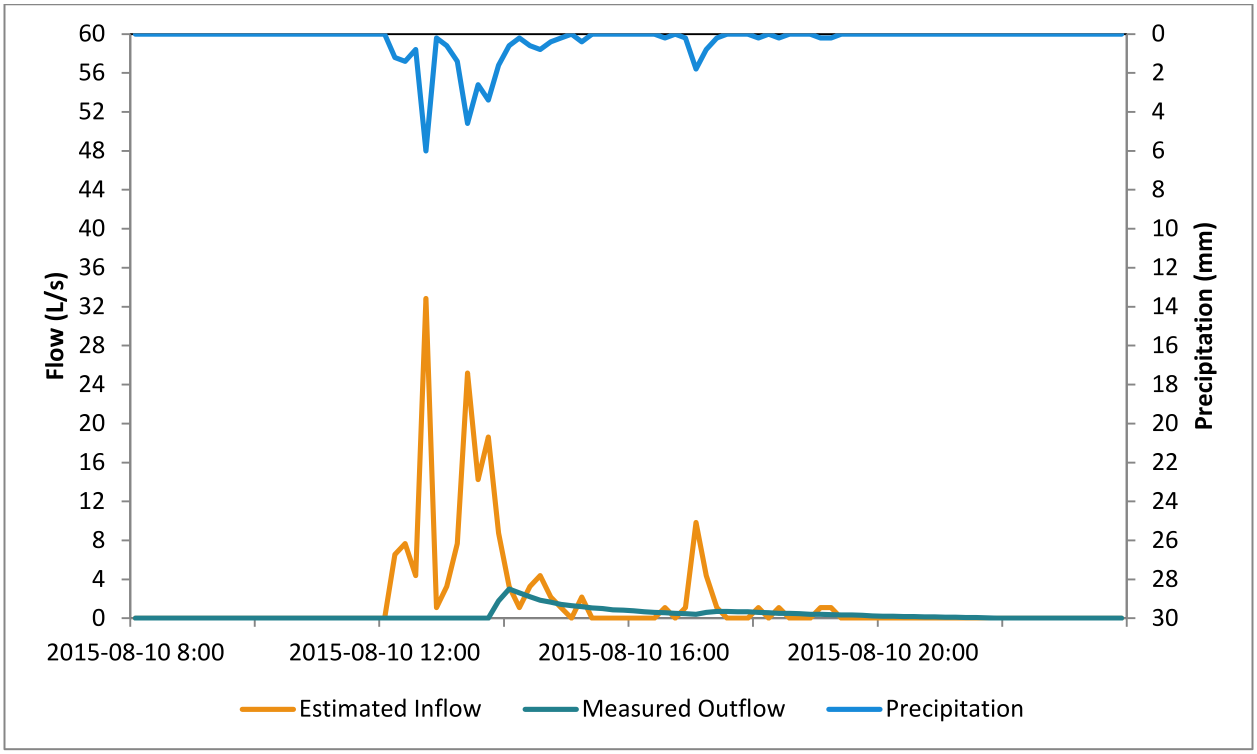


Figure 4-8 Hydrograph for Aug 10, 2015 (31 mm)

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 per cent peak flow reductions achieved for storms larger than the 2 yr event but smaller than the large July 8, 2013 event are summarized in Table 4-4. The measured peak flows were below the estimated pre-development peak flows (TIMG, 2010), far exceeding the predicted performance (**Table 3-2**).

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

Event Date	Total precipitation depth (mm)	Peak intensity (mm/hr)	Precipitation duration (hr:min)	Peak to peak lag (hr:min)	Peak flow reduction (%)	Depth retained (mm)
10 - 50 y events (55 – 71 mm)						
Jun 27 2015	62	13.2	32:50	0:40	88.0	49.9
May 30 2015	55.4	26.4	32:10	12:00	89.5	46.0
Jul 5 2013	60.2	117.6	9:30	0:20	90.2	46.9
5 – 10 y events (45 – 55 mm)						
Apr 29 2014	48.8	16.8	45:40	3:20	79.3	34.6
Nov 28 2011	46.4	8.4	25:10	7:20	66.0	43.2
Oct 18 2011	48.4	13.2	31:40	8:00	54.3	36.8
2-5 y events (33 – 45 mm)						
Jun 7 2015	33.4	40.8	14:10	6:50	90.1	23.7
Sep 5 2014	33.8	34.8	13:00	5:20	94.8	28.9
Jul 27 2014	38.8	12.0	19:20	5:40	79.7	30.3
Sep 20 2013	42	27.6	19:20	17:50	91.5	34.0
Jun 10 2013	36	25.2	21:00	15:30	84.0	28.1
Sep 8 2012	40.6	30	12:10	0:40	66.0	29.2
Aug 9 2012	45	55.2	32:50	11:20	85.5	31.4
Jul 31 2012	35	63.6	2:00	0:20	81.1	27.0
Aug 9 2011	34.6	20.4	6:00	0:50	90.6	33.5

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. For a rainfall event with a relatively simple time distribution, like the August 10, 2015 event illustrated above, the “peak to peak” lags can be interpreted. For this event, the peak outflow from the site was delayed by 1 hour and 40 min. However, in general, the calculated lags were variable and highly dependent on the rainfall distribution. For the June 7, 2015 event illustrated above, the peak to peak lag is 18 hours and 50 min. The highest rainfall intensity occurs early in the event. However, compared to no stormwater management, the peak flow comes much later in response to another high (but not maximum) intensity precipitation interval and the cumulative rainfall over a longer period. With no stormwater management, the response time is quick or flashy, leaving little time for infiltration or evapotranspiration. This results in more runoff entering creeks and streams, filling them more often and for longer periods during and after rain events. For the June 27, 2015 event, the hydrograph shows that the peak flow follows the peak rainfall by only 40 min. 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.

Although events up to 25 mm are the focus for volume reduction and objectives related to water balance and water quality, the volume reductions that can be achieved for large events is also of interest. The percentages of volume reduction achieved by large events are discussed in **Section 4.2.4**.

For 2015, data are available for water levels within two of the bioretention cells (4 and 6) and surface ponding depths in two of the cells (1 and 4). The water levels in Cell 4 do not rise above the invert of the underdrain. **Figure 4-9** shows the water levels in Cell 6 which do rise above the underdrain invert on dates that coincide with outflow at the downstream monitoring manhole.

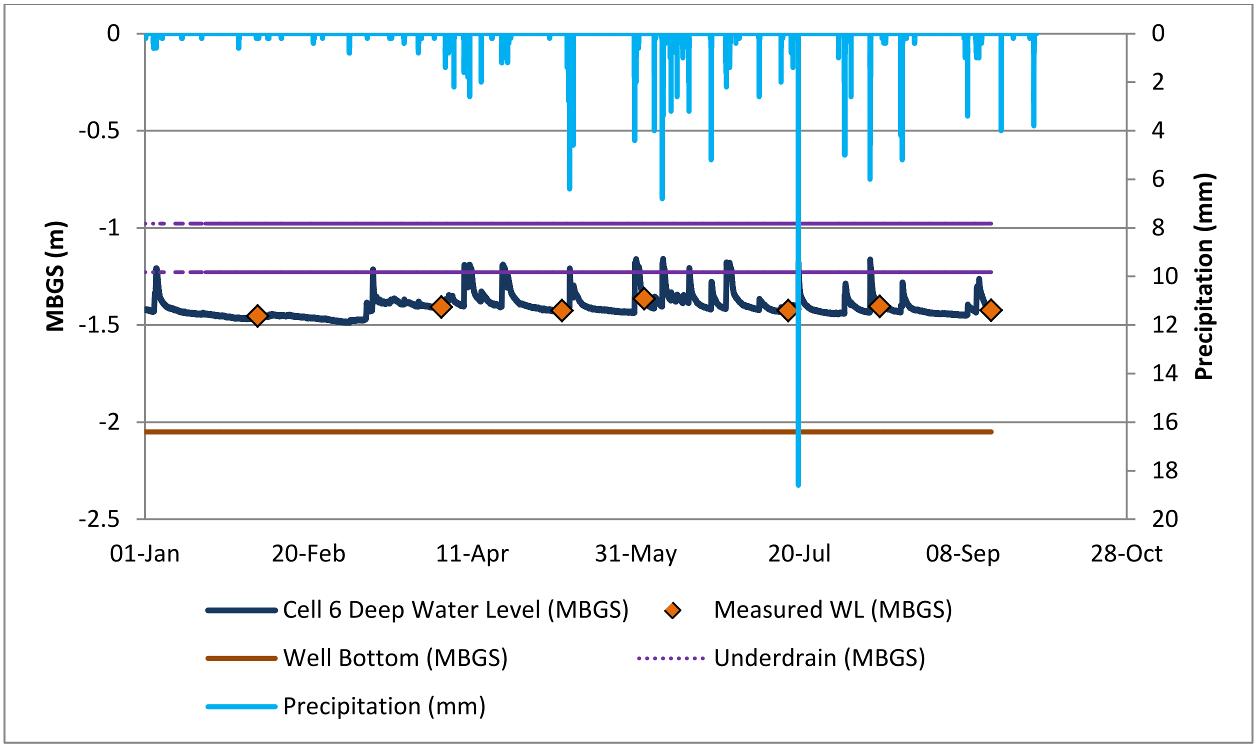


Figure 4-9 Water levels in bioretention cell 6 in 2015

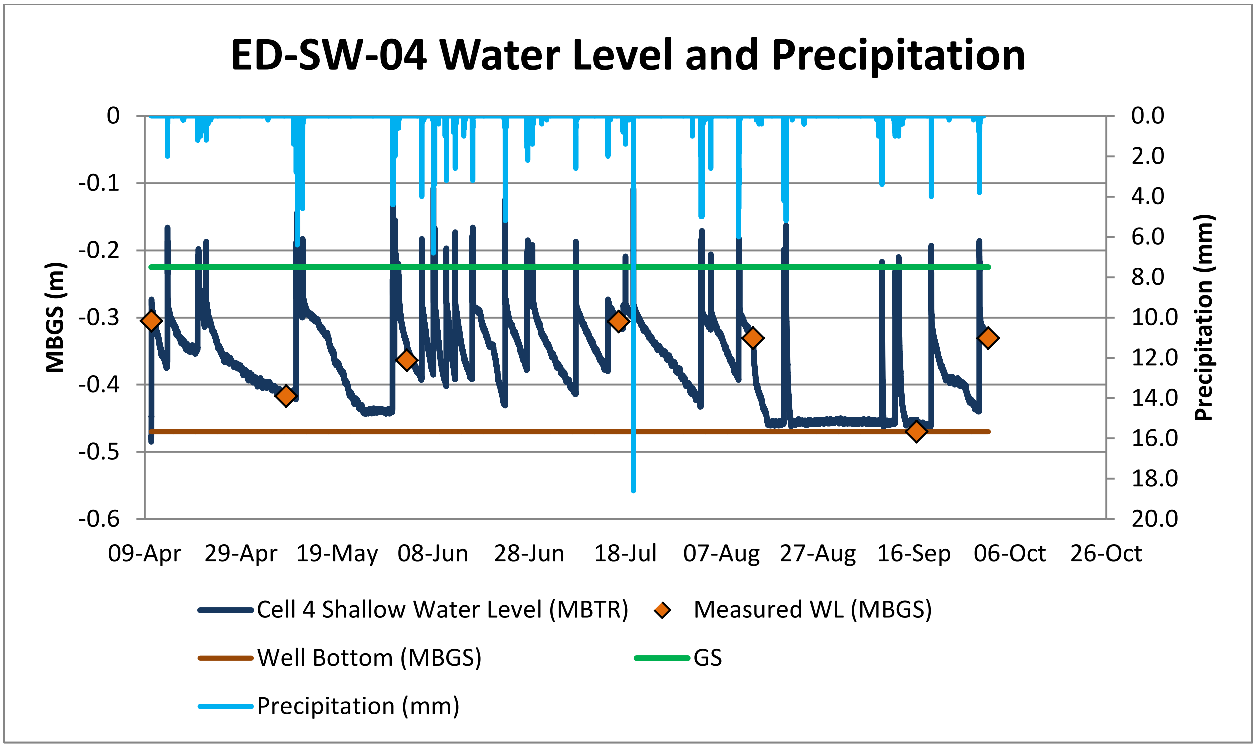


Figure 4-10 Surface ponding in bioretention cell 4 in 2015

The data plotted in **Figure 4-9** suggest that water is able to exfiltrate from the system between depths of 1.25 and 1.50 m below ground surface. However, the lower part of the storage layer remains saturated between events, reducing the storage capacity of the system. Within bioretention Cell 4, water levels drop to more than 2.0 m below ground surface.

Figure 4-10 shows the occurrences of surface ponding in Cell 4. The timing of ponding in Cells 1 and 4 was similar. Surface ponding often coincided with precipitation of more than 2.5 mm during the 10 minute recording interval (**Figure 4-10**). Not all of these events with high rainfall intensity and surface ponding produced outflow. Ponding depths did not rise to the elevation of the overflow outlet in either of the cells. Ponded water infiltrated into the media quickly (less than an hour after the high intensity rainfall period).

The smallest event to produce outflow was a 9.6 mm event on July 7, 2013. The smallest retention depths occurred on August 11, 2012 (8.5 mm) and May 14, 2014 (7.9 mm). All of these events were preceded with large precipitation depths (on the same or previous day). These results exceed the CVC stormwater management erosion control criteria to detain 5 mm on site. **Table 4-4** 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 23.7 mm (Jun 7, 2015). For comparison, the CVC erosion control criteria for new development with a stormwater management pond is to detain 25 mm for 48 hours.

4.2.3.1 Response to Extreme July 8, 2013 Event

The July 8, 2013 extreme rainfall event had a tremendous impact on urban infrastructure in Ontario. The event had a peak rainfall intensity of 242 mm/hr and a precipitation depth of 105 mm over nearly 5 hrs, measured at the Elm Drive site. The 5-day antecedent rainfall was 75 mm, with an average inter-event dry period of 15 hours. **Figure 4-11** shows the rainfall distribution for July 8, 2013 in the lower Credit River watershed.

Basement and street flooding due to surcharge of the storm sewer network, and flooding of some major roads in the GTA due to overtopping of bankfull flows caused significant damage to life and property during the July 8 event. It has been called the most costly natural disaster in Ontario's history with estimated damages of $1 billion (IBC, 2014).

The Elm Drive site was not designed to manage a storm of this magnitude; however, the site's response to such an event is useful to understand the role of LID with respect to its benefits for flood mitigation and infrastructure resiliency.

Volume reduction for this event was estimated to be in the range of 30 per cent. This is an estimate due to many variables during the large flood event including street longitudinal and cross flow, uncertainties with hydraulic conductivity, normal variability in measurements, rainfall-runoff assumptions and others. Reduction is greatest for smaller events since larger events cause the storage capacity of the filter media and the underdrain to fill, resulting in outflow, or bypass during extreme events. Results show that overall peak flow reduction was approximately 60 per cent. This percentage represents both flow entering the LID facility and accounts for flow bypass along the street. A lag time of approximately 20 minutes was observed between the inflow runoff peak and the outflow peak for this large event. This delay in the discharge of stormwater provided relief to an already overburdened stormwater system. Measurements and calculations for the July 8, 2013 event indicate that the facilities captured and treated approximately 65 per cent of runoff from this large event. A SWMM model was created to verify the influent flow in addition to using the Simple Method for this event. Refer to **Appendix C** for a detailed discussion on the SWMM model and the Simple Method.

Overall, Elm Drive is providing water quantity control and relief to the local stormwater system. This site has demonstrated its ability to retain a variety of event sizes and provide peak flow reduction, exceeding design expectations. The site performs exceptionally well for events under 25 mm, which constitute the greatest number of events in southern Ontario.

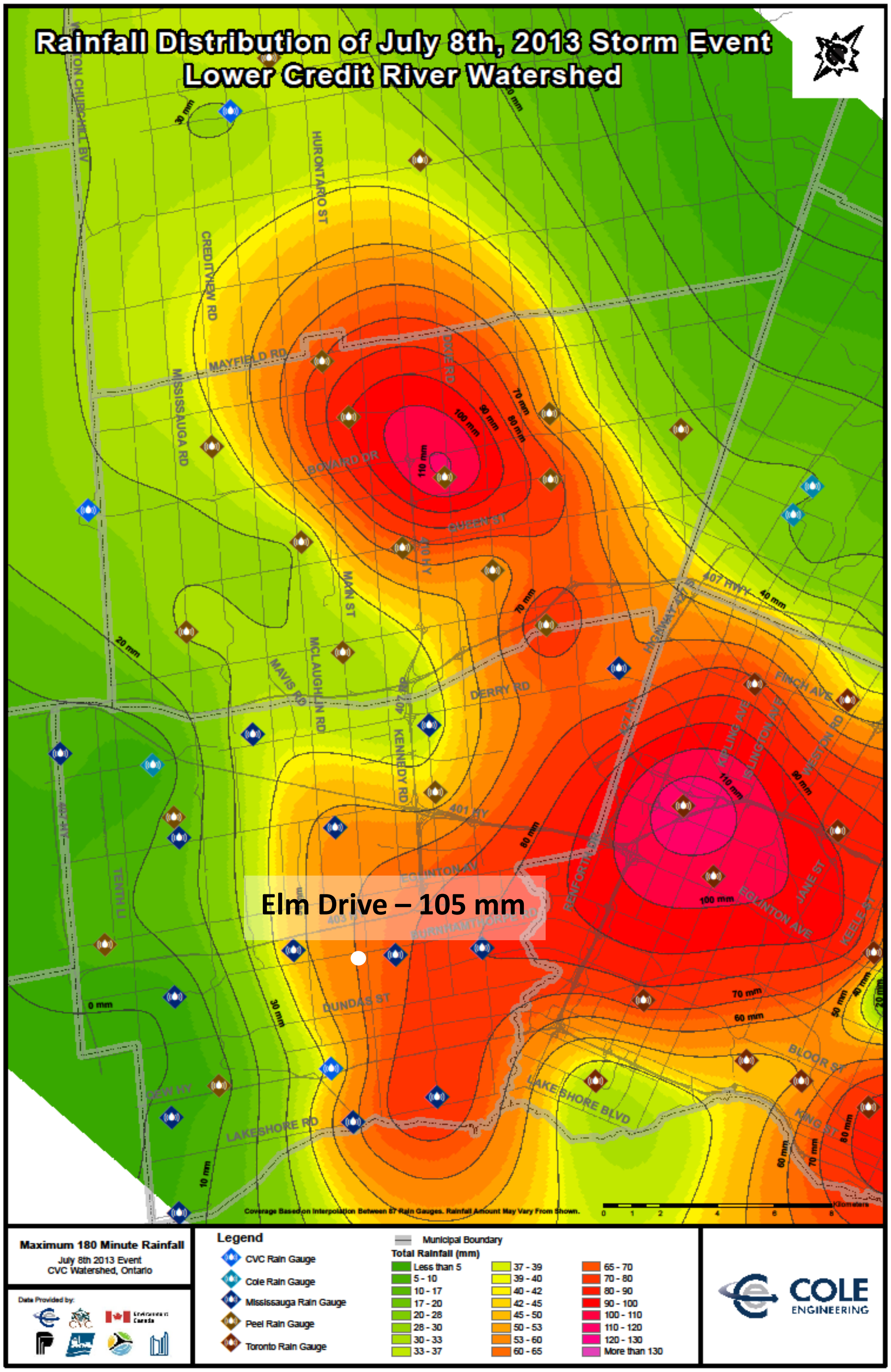


Figure 4-11 Rainfall distribution on July 8, 2013

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. Of the 283 events for which outflow was monitored, only 59 produced outflow. The overall runoff volume reduction was 80 per cent. The runoff volume reductions achieved for events of different sizes are provided below in **Figure 4-12.** For small events (up to 25 mm), the volume reduction was 93 per cent.

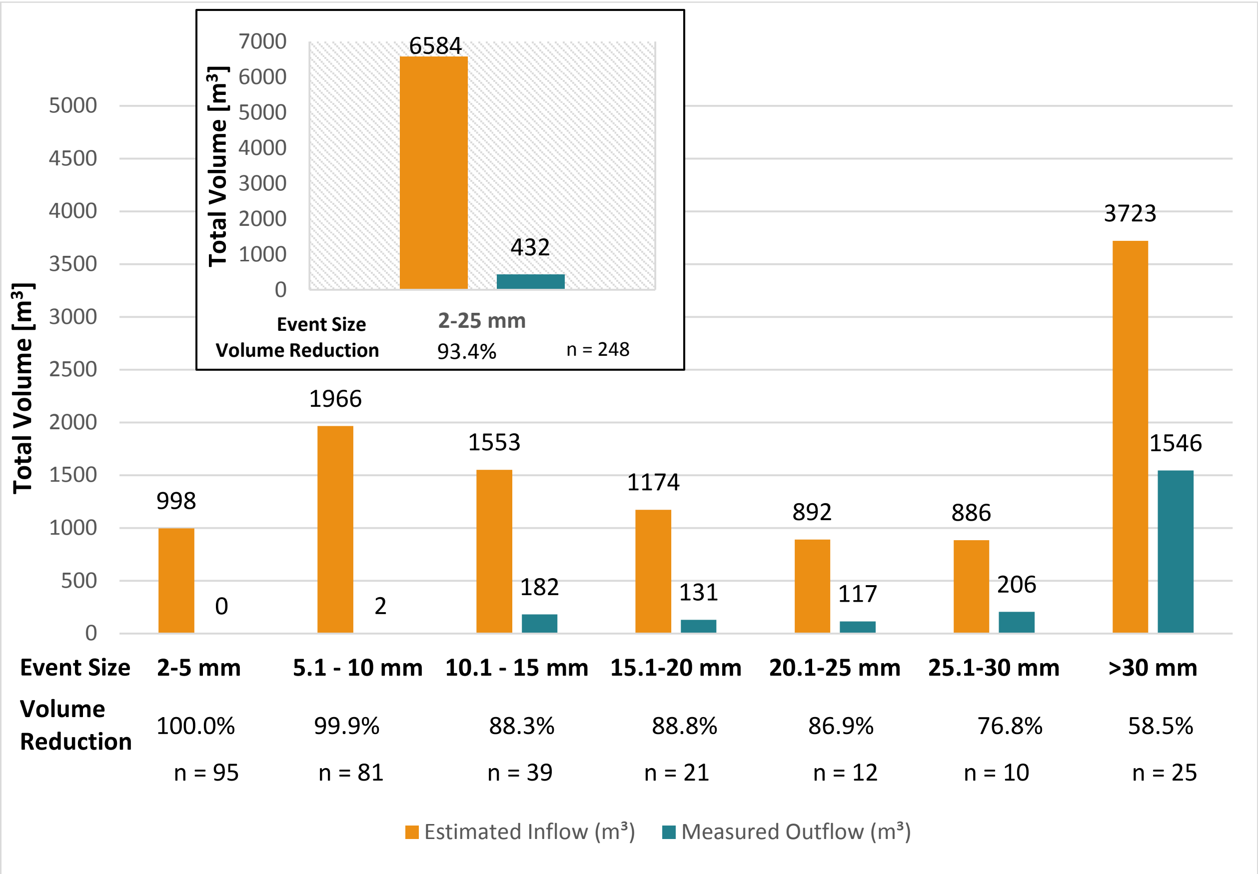


Figure 4-12 Runoff volume reduction achieved at Elm Drive, for different event size ranges, 2011 to 2015

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 reduction for events up to 25 mm was very similar (94 per cent) using this subset of the data. The 10-15 mm size class was most affected with 88 per cent volume reduction using the whole dataset and 95 per cent using the data set with the snowy period removed. The lower reduction for the 10-15 mm size class using the whole dataset can be explained by the occurrence of melt from precipitation that accumulated during previous events (belonging to different size classes).

The performance for events of comparable size was examined with respect to the potential importance of other factors such as peak intensity, duration or average intensity, and number of antecedent dry days (**Table 4-5**). The low volume reduction for April 19, 2015 may have been associated with saturated spring conditions. There was no obvious explanation for the relatively low percent volume reduction that occurred August 7, 2011 or June 7, 2015. The 26.6 mm on August 7, 2011 was followed by 34.6 mm on August 8, 2011. A 93.9 per cent volume reduction was achieved for the larger event on August 8 despite the wet antecedent conditions.

The expectation was that higher rainfall intensity or short antecedent dry period might result in lower percentage volume reduction. The August 27, 2013 event with higher peak and average intensity and shorter antecedent dry period compared to the events above (July 31, 2013) and below (September 10, 2014) it in **Table 4-5**, had a lower percentage volume reduction (by more than 4 per cent). However, the results were very mixed. This suggests that it is a combination of factors that contributes to the per cent volume reduction achieved on an event by event basis. It may also be necessary to refine the approach to quantifying antecedent conditions (e.g. amount of rainfall in preceding 3 days) and precipitation duration (e.g. focussing on the time over which most of the event precipitation occurs).

Table 4-5 Differences in percentage volume reductions for similar magnitude events

Event Date	Total precipitation depth (mm)	Peak intensity (mm/hr)	Precipitation duration (hr:min)	Antecedent Dry Period (Number of days)	Volume reduction (percent)
Aug 7 2011	26.6	38.4	8:20	2.7	47.7
Sep 23 2011	25.0	33.6	8:20	0.9	100
Sep 4 2012	25.2	50.4	12:00	7.8	97.3
Oct 23 2012	25.6	10.8	20:40	2.0	70.5
Oct 28 2012	28.4	7.2	31:50	0.6	93.1
May 28 2013	25.0	30.0	11:50	0.3	87.9
Jul 31 2013	31.6	10.8	18:20	3.8	79.4
Aug 27 2013	25.2	43.2	7:10	1.2	74.7
Sep 10 2014	27.0	25.2	11:40	4.2	79.1
Apr 19 2015	32.0	7.2	16:20	2.8	24.1
Jun 7 2015	33.4	40.8	14:10	1.8	43.2
Aug 10 2015	31.0	36.0	7:00	5.8	79.4
Sep 29 2015	26.6	22.8	5:20	1.1	81.0

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 total suspended solids (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 Elm Drive 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 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 LID systems at Elm Drive 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 volume was reduced by 93.4 per cent. 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. If a particular contaminant is not removed in the treatment system, its concentration in the effluent would be much higher (because the volume of effluent is reduced compared to the volume of influent). 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 Elm Drive site. Effluent concentrations will be compared to estimated influent concentrations and to receiving water objectives and effluent concentrations from similar LID practices in other North American locations. These comparisons can provide insights into preferred designs and advancements which may be needed.

Table 4-6 Provincial Water Quality Objectives and Canadian Environmental Quality Guidelines for selected metals, nutrients and other parameters of interest

Parameter	Unit	PWQO/CCME
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. (2014).

4.3.1 Effluent Concentrations

Twenty-three composite samples were collected during the mid-April through November periods between 2012 and 2015. **Table 4-7** summarizes the results of analyses of these samples with respect to event mean concentrations (EMCs). Influent concentrations are not measured at the Elm Drive site so estimates from the National Stormwater Quality Database (NSQD) are used.

Table 4-7 Summary of effluent EMC results

System	NSQD	Elm Drive		BMPDB (bioretention)
Parameter (units)	**Estimated influent EMC[1]**	**Range effluent EMC**	**Median effluent EMC**	**Median effluent EMC**
Total Suspended Solids (mg/L)	87.5	3-340	35	9.9
Total Dissolved Solids (mg/L)	NA	294-2010	554	NA
Nutrients				
Total Phosphorous (mg/L)	0.3	0.01-0.80	0.09	0.24
Ortho-phosphate (mg/L)	0.07	0.01-0.45	0.05	0.26
TKN (mg/L)	1.5	0.15-7.00	0.64	1.34
Nitrate + Nitrite (mg/L)	0.62	0.84-3.12	1.36	0.39
Ammonia (mg/L)	NA	0.02-5.40	0.08	NA
Metals				
Cd (µg/L)	0.41	0.05-0.46	0.20	0.07
Cu (µg/L)	18	3.40-18.6	10.30	5.33
Fe (µg/L)	NA[2]	62-2820	391	1,027
Pb (µg/L)	16.8	0.30-17.9	1.90	0.19
Ni (µg/L)	10	0.50-8.20	1.30	4.53
Zn (µg/L)	110	4.00-91.0	17.0	12.0

[1] Elm Drive influent is NSQD medians processed by Robust regression on Order Statistics (ROS) for residential and residential + mixed used sites in EPA Rain Zone 1.These values include data from all seasons.
[2] Insufficient data available in NSQD to estimate influent concentration and load.

Only two water quality analyses were available for the December through mid-April, “winter” period. With the exception of dissolved solids, including these two samples did not change the median event mean concentrations provided in **Table 4-7**. The median event mean concentrations for the effluent from the Elm Drive site were below the estimated influent concentrations for all parameters except nitrogen in the form of nitrate and nitrite.

The results are also compared to typical EMCs achieved by other similar LIDs, per the International Stormwater Best Management Practices Database (BMPDB). The BMPDB values represent LIDs that are used to treat stormwater runoff from a broad range of land uses. Again with the exception of nitrogen in the form of nitrate and nitrite, the median concentration of nutrients in the effluent from the Elm Drive site was lower than the median concentrations from sites in the BMPDB. The median concentrations of total suspended solids and the metals except iron and nickel were higher than those in the BMPDB.

The effluent concentration results for selected parameters are also shown in **Appendix D.** The time series plots show the concentration of each sampled event for two groups of parameters, nutrients and metals. Probability plots, which show the percentage of samples with concentrations below different values, are also included for nutrients and metals. 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 25th and 75th percentile values and the whiskers extend to the 5th and 95th percentile values.

Both sets of figures show that, for most parameters, the EMC values on different dates vary considerably. The time series show that most of the events early in the monitoring period had lower concentrations of total suspended solids as well as metals compared to events later in the monitoring period.

Since only two samples were available for the December through mid-April "winter" period, separate median EMCs were not calculated for the seasons. However, **Table 4-8** presents the "summer" period median EMCs for selected parameters for comparison to the two available samples.

Table 4-8 Event mean concentrations of a winter rain and melt event

Season	TSS (mg/L)	TDS (mg/L)	Chloride (mg/L)	Sodium (mg/L)	TP (mg/L)	Cu (µg/L)	Ni (µg/L)	Zn (µg/L)
Median EMC for mid-April to November Samples (23)	35	554	160	116	0.09	10.3	1.30	17
Jan 13, 2013 Rain	14	812	270	177	0.077	5.4	0.50	14
Mar 11, 2015 Melt	270	1780	830	468	26	23	8	57

The January 13, 2013 rain event had higher total dissolved solids, chloride and sodium concentrations as would be expected. The event mean concentrations of other parameters were actually less than the median event mean concentrations for samples collected in the period less affected by winter maintenance activities. In contrast, the melt sample had much higher concentrations for all of the parameters in **Table 4-9**.

4.3.2 Pollutant Load Reduction

The inflow loads were calculated using median event mean concentrations from the NSQD and the inflow volumes estimated using the Simple Method. 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, the median event mean concentrations for Elm Drive were used. The analysis includes both events that generated outflow and events that did not. The total estimated influent and effluent loads were obtained by summing the results for all events. **Table 4-9** provides the load reduction results calculated for parameters of concern.

Table 4-9 Percentage load reductions

Parameter	Inflow load (g)	Outflow load (g)	Estimated load reduction (%)
Total Suspended Solids	979300	117600	88
Total Phosphorous	3360	302	91
Ortho-Phosphate	783	113	85.6
TKN	16790	1500	91.1
Nitrate + Nitrite	6940	2770	60.0
Cadmium	4.59	0.48	89.6
Copper	202	22.9	88.6
Iron*	NA	1300	NA
Lead	188	8.81	95.3
Nickel	112	4.17	96.3
Zinc	1230	58.7	95.2

*Insufficient data available in NSQD to estimate inflow concentration and load.

Figure 4-17 and **Figure 4-18** show the influent and effluent mass loads of total suspended solids and total phosphorous based on event size. The elimination of outflow from events less than 10 mm, and very high volume reduction for other events less than 25 mm, led to the high percentage pollutant removal.

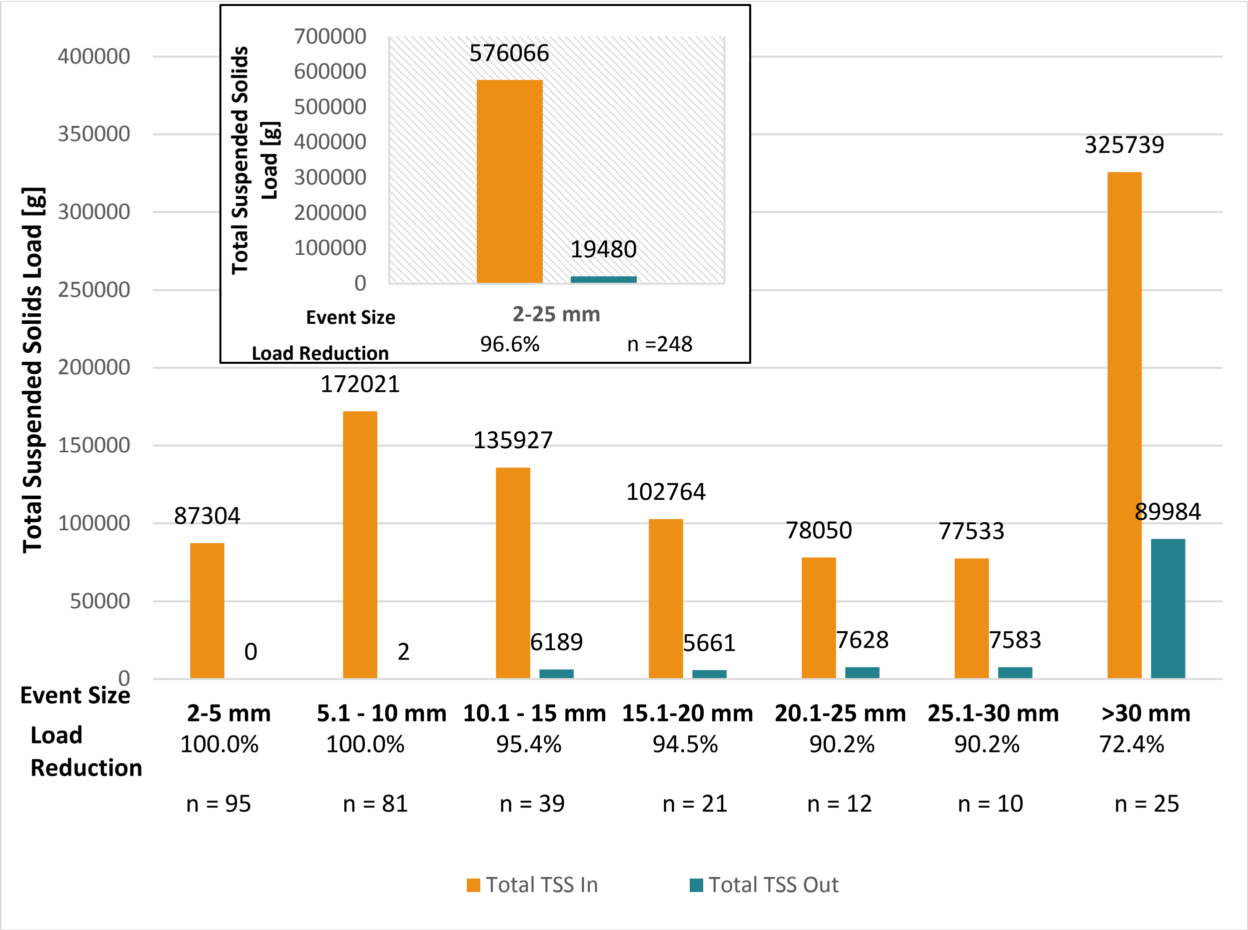


Figure 4-13 Load reductions of total suspended solids for different event size ranges, 2012-2015

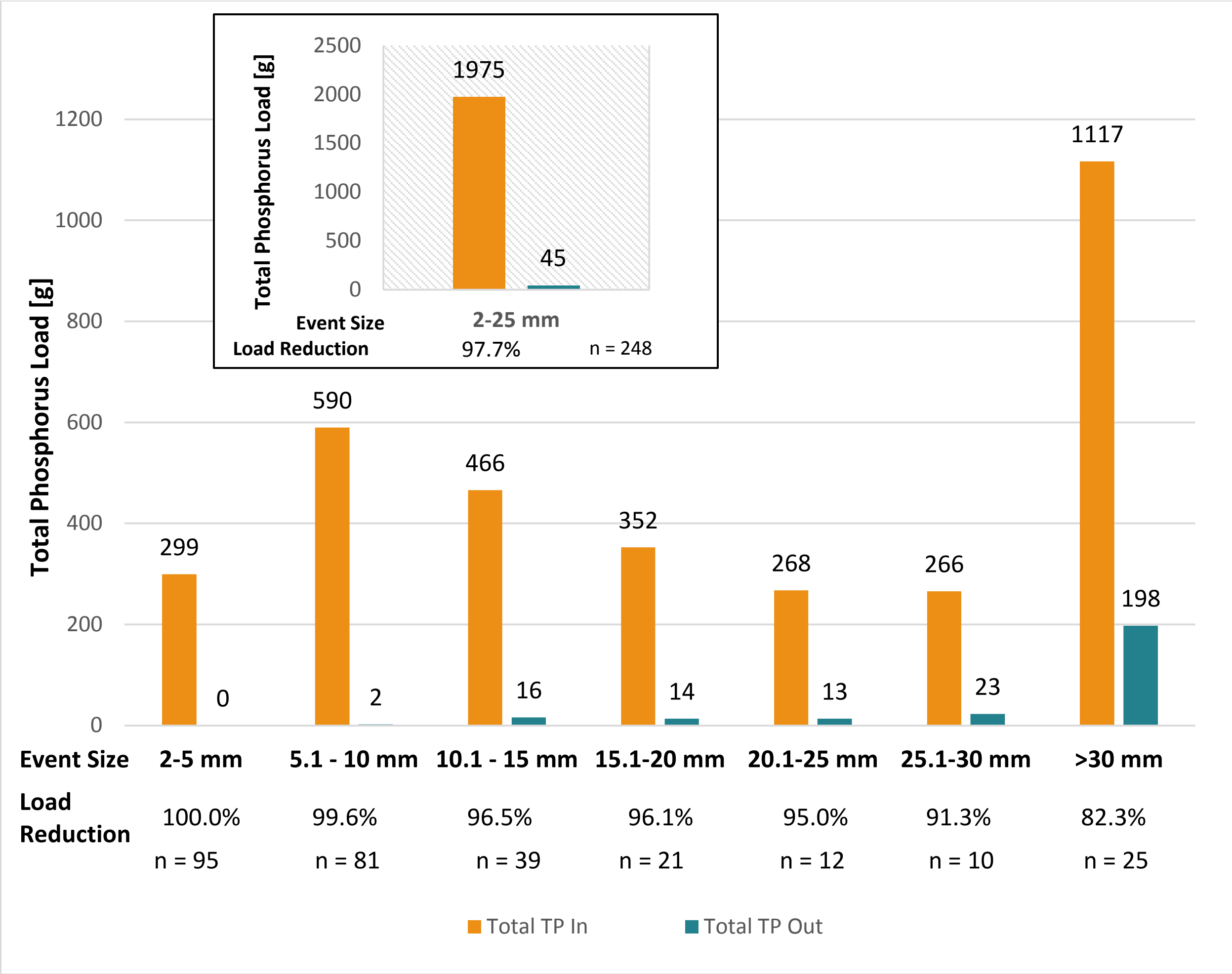


Figure 4-14 Load reductions of total phosphorous for different event size ranges, 2012-2015

The analysis included the extreme July 8, 2013 event. The event mean concentrations for all parameters except lead and zinc were within the range of the event mean concentrations for other events. The measured event mean concentrations of nickel and zinc were higher than those of other events. Although the event mean concentration of total suspended solids was within the range of other events, it was high during the July 8 event and, combined with the very large outflow volume, the event contributed to the relatively high effluent load (and lower mass reduction) of the >30 mm bin. However, the water quality performance was good even for these large events (more than 70 per cent mass removal for all parameters of concern except nitrate).

The water quality analysis confirms that the treatment train at Elm Drive is performing well with respect to reducing the contaminant loads from the site on downstream watercourses. The LID system at Elm Drive achieved an 88 per cent TSS load reduction for the 2011 to 2015 study period, based on influent loads estimated using influent concentrations from the NSQD. This exceeds the stormwater management criteria requiring 80 per cent TSS removal. More than 85 per cent mass removal was achieved for all parameters except nitrogen in the form of nitrate and nitrite, for which 60 per cent mass removal was achieved.

4.4 Thermal Mitigation

When precipitation events occur on warm sunny days, the stormwater flows over hot roads, sidewalks and rooftops and absorbs the heat stored within the impervious surface through conduction. This stormwater becomes warmer and, in most cases, flows into the nearest stormwater sewer system followed by the local receiving body. The sudden increase in temperature caused by the stormwater runoff in these stream reaches can have significant negative impacts on freshwater habitat, including the growth and survival rates of aquatic species and concentrations of oxygen, nutrients and pollutants dissolved in the water.

4.4.1 Background

Peer-reviewed studies have provided evidence that LID is capable of reducing thermal pollution from stormwater runoff (Hester and Bouman, 2013; Wardynski et al., 2013; Jones et al., 2012; Sabouri et al., 2013; Natatajan et al., 2012). Although these studies have not been completed in Ontario or in similar climates, they provide valuable insight into the thermal monitoring program at Elm Drive. The Elm Drive LID facility design incorporates features used in previous studies for reducing thermal impacts from stormwater runoff. **Figure 4-19** illustrates the location of these LID features.

4.4.2 Methodology

The bioretention cells at Elm Drive are being evaluated for thermal mitigation potential by developing event mean temperatures and thermal loads of inflows and outflows. Event mean temperature is the average temperature of water flowing in and out of the LID facility during an event, whereas thermal load is the amount of energy introduced to the LID facility from heat transferred to stormwater from surface runoff. In order to assess thermal mitigation and calculate event mean temperatures, HOBO pendant temperature loggers were deployed at the inflow catch basin and at the outflow manhole. Both loggers are set to record temperatures at 10-minute intervals. Refer to **Appendix G** for further details of the methodology and analysis used for determining thermal mitigation through the LID.

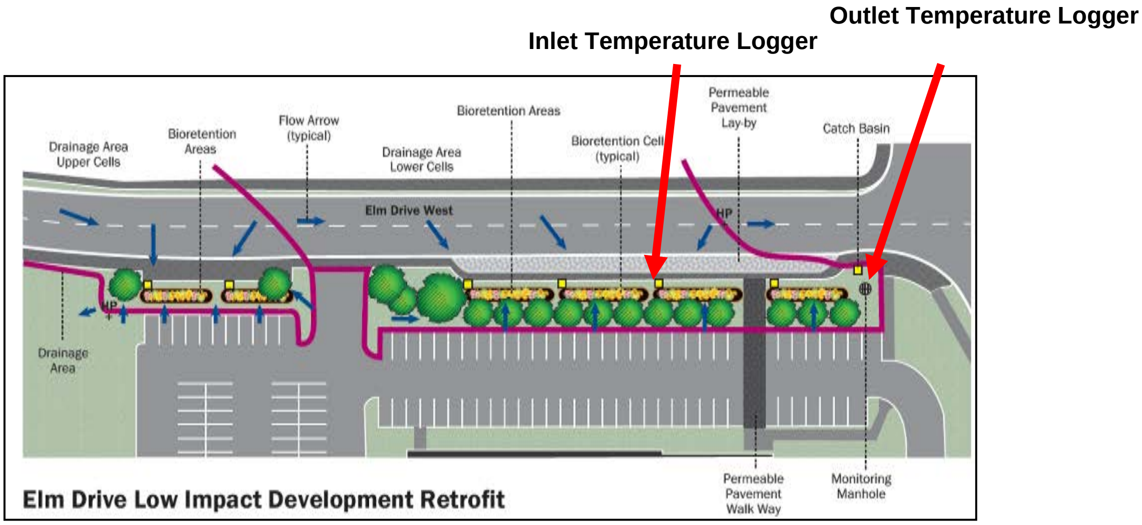


Figure 4-15 Overview of the Elm Drive retrofit and location of inlet and outlet temperature loggers

4.4.3 Results

Studies have demonstrated that LIDs which include a bioretention component have the highest potential to decrease thermal loading from urban watershed. CVC has been monitoring stormwater inflow and outflow temperatures at the Elm Drive LID treatment train since the spring of 2013. The focus of the monitoring is inclusive to the warmest months of the calendar year, from May to September, where the effects of thermal loading from stormwater runoff are the greatest in urban streams. Through all three years the data suggests the treatment train significantly improves thermal loading impacts within all event sizes.

Figure 4-16 Illustrates the average thermal load reduction for all storm events divided into 10 mm increments. The decrease in effluent volume through runoff storage within the LID facility is the leading factor in producing high thermal and temperature reductions at Elm Drive. Additionally, any effluent produced must pass through cooler permeable soil where thermal energy is transferred. The treatment train provides high thermal reduction in all events ranges and nearly 100 per cent reduction during smaller more frequent events.

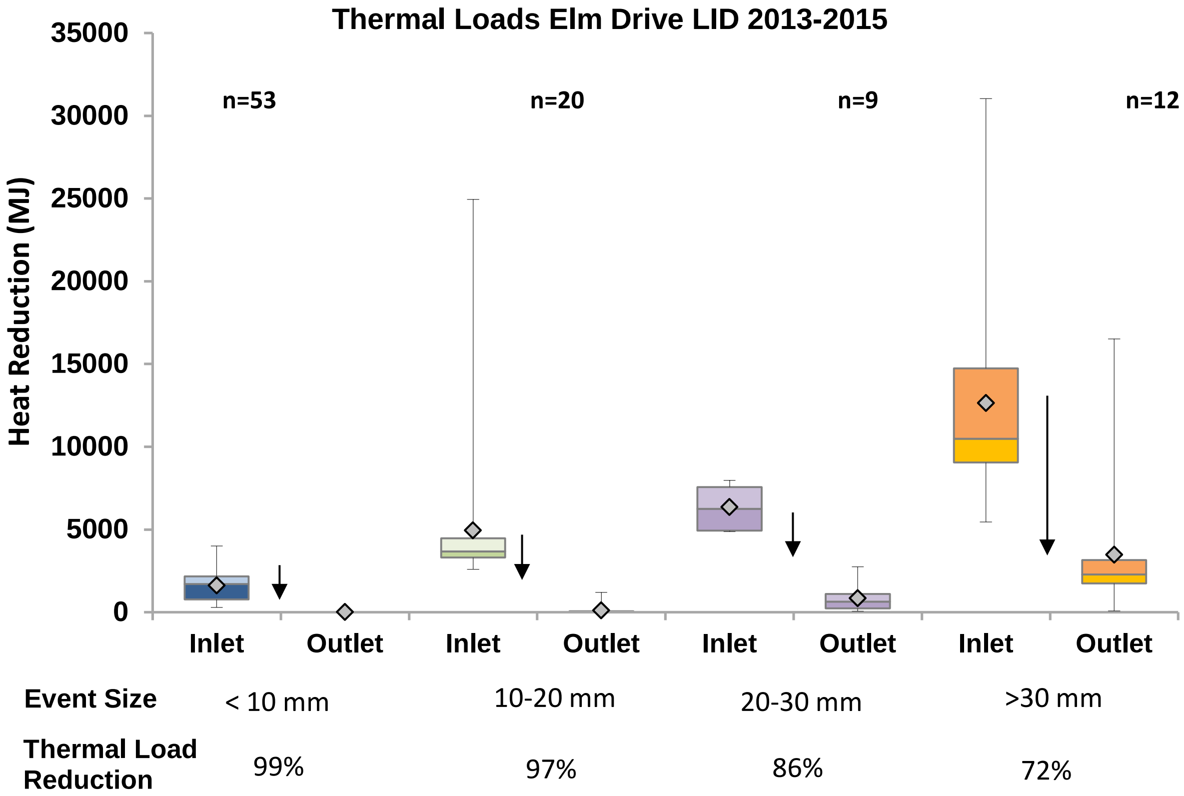
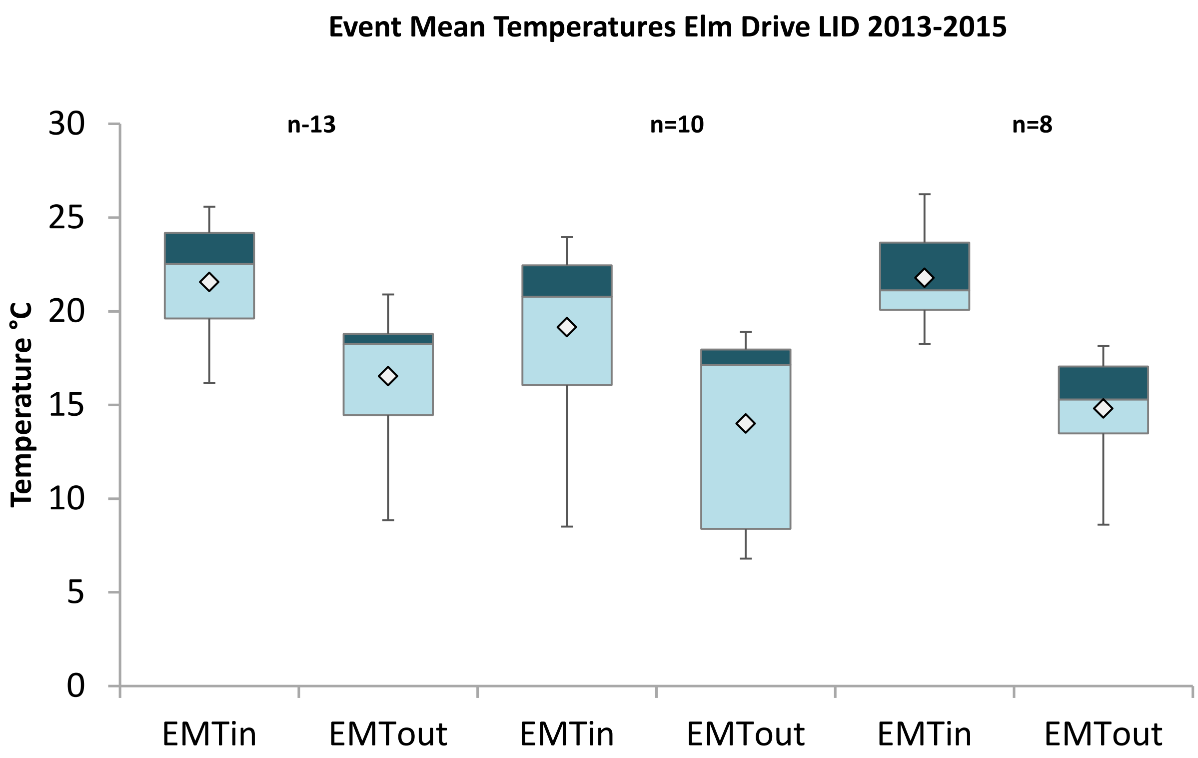


Figure 4-16 Thermal loading results from 2013-2015

To demonstrate how the treatment train provides thermal reduction specifically during events where outflows are generated, **Figure 4-17** provides event mean temperature (EMT) results for all outflow events during the three year monitoring period.



Year	2013	2014	2015
Average EMT Reduction:	**5°C**	**5°C**	**7°C**

Figure 4-17 Event mean temperature 2013-2015 results

Consistent EMT reductions are provided by the LID each year, demonstrating the need to implement LID designs upstream of known sensitive streams habitats. These results suggest similar LID technologies can be used to meet Ministry of Natural Resources and Forestry requirements in protecting Redside Dace habitats. The requirements include discharge temperature < 24°C from stormwater management facilities and no stormwater runoff from events <15 mm (MNRF, 2011).

4.5 Soil Analysis

The LID approach at Elm Drive 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 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.

4.5.1 Soil Sampling Methodology

Soil sampling occurred in the bioretention units that receive runoff from the surrounding catchment area. **Figure 4-18** indicates the bioswales and locations where samples were collected. Sampling occurred October 2, 2013 and 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).

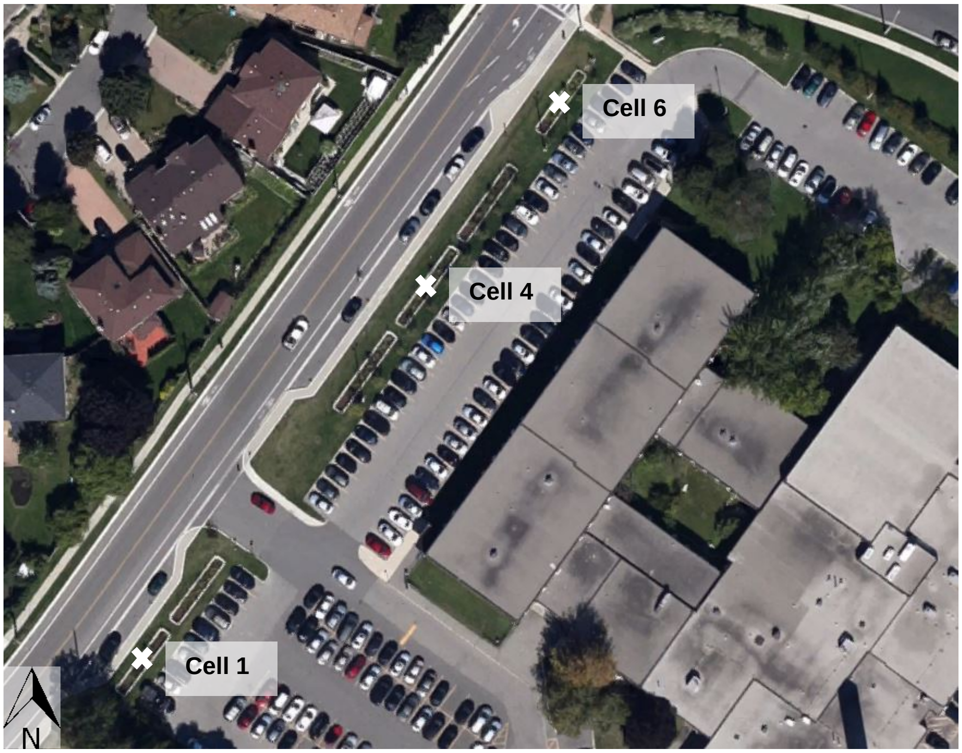


Figure 4-18 Bioretention cell sampling locations

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 even for Elm Drive 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.

4.5.2 **Soil Sampling Results**

The concentrations of the soil quality parameters that correspond to the defined water quality parameters of interest are summarized in **Table 4-10**. Results for all parameters tested can be found in **Appendix F.** 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 few trends in the soil results for the parameters of interest. The concentrations of orthophosphate and total kjeldahl nitrogen were higher in the upper soil layer for all bioretention units that were sampled for both years. Conversely the metals concentrations showed less of a trend. Calcium and magnesium had increasing concentrations with depth and the deep soil layer concentrations were higher in 2014 compared to 2013. PAH compounds (**Appendix F**) also had many concentrations below the detection limit, however there tends to be more detects and higher concentrations in the upper soil layer; this is particularly evident in 2014.

Sampling suggests that concentrations for some parameters, such as iron and zinc, are increasing with time. It is difficult to make direct comparisons regarding contaminant concentrations between bioretention cells because the cells have different plant combinations, which may provide varying nutrient uptake rates. In addition, due to the location of the catch basins receiving runoff and the bioswale inlet locations, the six cells may not be receiving equal amounts of stormwater runoff from the road. Since the concentrations of contaminants in the 2013 and 2014 samples are well below the specified guidelines, the bioswales at Elm Drive have not been contaminated by stormwater runoff. A longer study period with additional soil sampling will provide more insight on the increase of concentrations with time.

Table 4-10 Soil sampling results for Elm Drive, 2013-2014

Parameter	Detection Limit	Guideline		2013 Cell 1 Shallow	2013 Cell 1 Deep	2013 Cell 4 Shallow	2013 Cell 4 Deep	2013 Cell 6 Shallow	2013 Cell 6 Deep	2014 Cell 1 Shallow	2014 Cell 1 Deep	2014 Cell 4 Shallow	2014 Cell 4 Deep	2014 Cell 6 Shallow	2014 Cell 6 Deep
		CCME [a]	MOE [b]												
Cadmium (ug/g)	0.5	10	1.2	[d]	[d]	[d]	[d]	[d]	[d]	[d]	[d]	[d]	[d]	[d]	[d]
Copper (ug/g)	2.0	63	140	6.8	8.6	7.4	7.4	11	6.7	6.6	7.8	8.7	7.6	6.7	8.9
Iron (ug/g)	50.0	[c]	[c]	4700	4600	4600	5100	6600	4400	4900	6600	5800	6700	5400	5700
Lead (ug/g)	5.0	140	120	[d]	5.8	5.6	9.7	[d]	6.6	[d]	11	[d]	6.6	[d]	[d]
Nickel (ug/g)	5.0	45	100	[d]	[d]	[d]	[d]	[d]	[d]	[d]	[d]	[d]	[d]	[d]	[d]
Zinc (ug/g)	5.0	200	340	12	16	15	39	20	15	17	39	18	34	15	19
Orthophosphate (ug/g)	0.2	[c]	[c]	1.5	1.4	1.5	0.9	4.4	2	1.6	0.6	1.3	0.4	5	1.2
Total Kjeldahl Nitrogen (ug/g)	10.0	[c]	[c]	380	351	346	231	594	415	316	165	665	127	771	362
Nitrate + Nitrite (ug/g)	3.0	[c]	[c]	[d]	[d]	[d]	[d]	[d]	[d]	[d]	[d]	[d]	[d]	[d]	[d]

[a] Residential/Parkland
[b] Shallow Soil, Not Potable, Residential/Parkland/Institutional, Coarse Texture
[c] Indicates no guideline available
[d] Indicates result is below the detection limit

4.6 Site Inspection and Maintenance

The stormwater facilities at Elm Drive are designed to trap debris, sediments and other stormwater pollutants that will accumulate and will require periodic removal as maintenance. Landscaping and healthy vegetation are also important features of LID as the plants absorb many stormwater pollutants. This requires maintenance for both aesthetic reasons and to promote optimal performance. Understanding the maintenance needs of these systems is a priority for the program and property owners to assess if these technologies are feasible from a municipal-wide perspective.

Long-term infrastructure assessment is needed (both quality and quantity performance) to capture when a decline in performance occurs and how 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 will benefit asset management information

The City of Mississauga is responsible for the maintenance of the site, with some assistance from the Peel District School Board (PDSB) and CVC's Conservation Youth Corp (CYC).

Scheduled maintenance duties that are to be performed by the City of Mississauga include:

- Trash and debris removal
- Snow removal
- Mulching
- Weeding
- Tree and shrub pruning
- Fence maintenance
- Sign repair

The PDSB is responsible for mowing the grass surrounding the bioretention cells. Since the site was constructed, CYC has provided at least 168 volunteer hours since the site was constructed, with approximately 60 to 70 hours annually since the site was established. They contribute by helping with maintenance tasks such as weeding, removing garbage, mulching and planting.

To aid in their effort, CVC monitoring staff have been collecting data on maintenance activities performed and inspecting conditions of the bioretention planters and permeable pavement at Elm Drive on a monthly basis. A standard site inspection checklist has been created and is used by staff during each site visit (**Appendix E**). This checklist along with interviews with property owners has led to the creation of a maintenance database, to track maintenance tasks and needs to help determine lifecycle costs.

4.6.1 Analysis and Results

Table 4-11 summarizes some of the trends from the database. Based on the inspection checklists from 2-13 to 2015, this table summarizes the percentage of time a contributing drainage area to the LID facility is ranked good, mild, moderate or severe. With this system, a good ranking means that the site is generally clean and well maintained, with the scale escalating through mild and moderate to severe. A severe ranking would mean that the facility's ability to treat the runoff is hindered.

Table 4-11 Summary of findings from inspection checklists, 2013-2015

Contributing Drainage Area	Average Category	% Good	% Mild	% Moderate	% Severe
Contributing Area Sediment	Mild	80%	14%	6%	0%
Contributing Area Trash/Debris	Good	94%	6%	0%	0%
Facility Sediment	Mild	77%	17%	3%	3%
Facility Trash/Debris	Mild	51%	23%	9%	17%
Inlets Sediment	Mild	80%	20%	0%	0%
Inlets Trash/Debris	Moderate	47%	21%	12%	21%
Outlets Sediment	Good	97%	3%	0%	0%
Outlets Trash/Debris	Mild	86%	9%	3%	3%
Permeable Pavements Sediment	Moderate	34%	31%	26%	9%
Permeable Pavements Trash/Debris	Good	86%	11%	3%	0%
Vegetation Weeds/Invasives	Good	66%	26%	0%	9%

Examples for each ranking; a visual legend is included in Appendix E:

Good: *Little to no sediment accumulation on the road, permeable pavement and in the bioretention cells; few weeds present in the bioretention cell; little to no trash or debris is present in the bioretention cells or surrounding area; and the bioretention cell inlets are clear and are able to accept runoff.*

Mild: *Some sediment is present on the road or permeable pavement; some weeds are present in the bioretention cells; some trash is present in the bioretention cell or drainage area.*

Moderate: *Sediment is accumulating on the permeable pavement or in the bioretention cells; a fair amount of weeds or dense vegetation is present in the bioretention cells; trash or debris are present in the bioretention cell and may be starting to impede runoff from entering the system; maintenance is required.*

Severe: *Sediment is clogging the permeable pavement and not allowing runoff to infiltrate; vegetation or weeds have overgrown the area and need to be trimmed back; large amounts of trash or debris are captured in the bioretention cells or surrounding area; incoming runoff has caused erosion in the bioretention cell; maintenance is required and/or overdue.*

Litter accumulation is an ongoing problem due in part to the bioretention cells sitting below grade. This is also a high traffic area, due to the facility's proximity to the school and local shopping mall. Inlets to the facility are also experiencing litter and debris accumulation, especially in the spring and fall. During the spring this is likely reflecting garbage that has accumulated during the winter, while the fall likely reflects leaf debris. For this reason the City's maintenance schedule involves a major cleanup in the spring, followed by regular maintenance throughout the year.

Figure 4-19 Debris and leaf litter in a bioretention cell

Vegetation within the bioretention cells is now well established. There are some areas with bare soil, indicating that mulch has been removed over time due to inflows from the catch basins. Inspections show that maintenance to the plants in the bioretention cells is needed throughout the year, primarily in the spring and fall. When plants are starting to grow in the spring, weeds have the chance to emerge as well. If not removed, they may take over the cell. In the fall, plants need to be trimmed to promote growth in the spring as they die back over the winter.

In July, 2015 the City of Mississauga cleaned the catch basins that receive runoff from the road and convey stormwater to the bioretention planters. This involved removing debris from the catch basin sumps and rinsing the catch basins with water. The pipes that convey stormwater from the catch basins to the bioretention planters were also flushed with water to remove sediment and debris.

Figure 4-20 Catch basin maintenance in July 2015

Staff also inspect the permeable pavement sidewalk and laybys. The sidewalk condition appears to be relatively consistent over time with little sediment accumulation. Since the permeable sidewalk is located in an area where smokers congregate, cigarette butts tend to become lodged between the paver joints. This reinforces the need to implement the right LID in the right location, or to account for the land use (e.g. by installing a facility to place cigarette butts). To avoid this design issue, a site visit by designers is warranted. This will help them to understand how the site is being utilized on a daily basis.

Figure 4-21 Cigarette butts caught in permeable paver joints

The condition of the permeable laybys appears to be declining over time, due to sediment accumulation; CVC staff have observed some evidence of clogging for 60 per cent of their inspection visits. The laybys are heavily travelled areas that are frequently used by vehicles. Snow is stored on the laybys throughout the winter months, which tend to carry dirt and sediment from the road.

Erosion is typically observed to be negligible in the bioretention cells, however since mulching may not have been performed in 2015, increasing areas of bare soil has been observed in the spring and fall of that year, highlighting the importance of regular mulching.

The continuation of maintenance activity information will help CVC determine the maintenance requirements and lifecycle costs of LID features. These observations also speak to the importance of understanding the land use and choosing the best suited BMP for the area.

5 DISCUSSION

The objectives of the Elm Drive project were outlined in **Section 2**. A good data set is now available to evaluate the hydrological and water quality performance of the green infrastructure at Elm Drive. The discussion will reference CVC's SWM criteria for flood control, erosion control, water quality and recharge. The findings will be related to the sizing and design of the systems.

5.1 Stormwater Management Criteria

5.1.1 Resilience of Stormwater Infrastructure

Green infrastructure such as permeable pavement and bioretention systems can reduce flow frequency and rates. This is expected to reduce stress on elements of the downstream stormwater conveyance system which can provide total lifecycle 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. 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.

Fifteen events (summarized in **Table 4-4**) with magnitudes ranging from 33 to 62 mm, occurred during the monitoring period. Peak flow reductions ranging from 66 to 95 per cent were estimated during these events. Peak flow reductions of this magnitude for minor events could reduce the size of conveyance system. Or, a system of the same size may be able to convey flows from larger events (which may become the new design event for minor systems) in future.

The July 8, 2013 event had a magnitude of 105 mm, with nearly all of this precipitation falling in the first 2 hours. The estimated peak flow reduction for this event was 40 to 60 per cent. This demonstrates the potential for widespread implementation of green infrastructure to contribute to mitigation of damages from such large, intense storms.

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 all systems. 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 infiltrate into the native materials. Even though the native soils underlying the Elm Drive site were determined to have very low hydraulic conductivity, a substantial depth can infiltrate over hours and days in many cases. The storage volume below the underdrains within the bioretention cells allowed the intercepted stormwater to infiltrate during inter-event periods. The underlying materials may also have cracks or fractures that increase the site scale hydraulic conductivity and opportunity for percolation of water to the underlying groundwater system. The data collected in Cell 6 during 2015 provided evidence that infiltration is occurring as the water levels never rose above the invert of the underdrain.

5.1.3 Erosion

The erosion control criterion is detention of 5 mm. The criteria has clearly been met if it can be demonstrated that 5 mm can be retained (does not become outflow to storm sewers and downstream watercourses). 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 fifteen events greater than 33 mm summarized in **Table 4-4**, at least 24 mm was retained. Considering all events, the smallest event to produce outflow was a 9.6 mm event on July 7, 2013. The smallest retention depths occurred on August 11, 2012 (8.5 mm) and May 14, 2014 (7.9 mm). These smaller events that produced outflow were preceded with substantial precipitation amounts (on the same or previous day). These results suggest that it should be possible to set the bar higher with respect to the 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 total suspended solids (TSS) removal). The LID system at Elm Drive achieved an 88 per cent TSS load reduction for the 2011 to 2015 study period, based on influent concentrations from the NSQD. This exceeds the stormwater management criteria requiring 80 per cent TSS removal.

More than 85 per cent mass removal was achieved for all parameters except nitrogen in the form of nitrate and nitrite, for which 60 per cent mass removal was achieved.

5.2 Design

Achieving the water quality objectives depends on capture of the design event. Aside from the extreme July 8, 2013 event, there were no documented instances of runoff from the road and permeable pavement by-passing the bioretention system.

No overflows within the bioretention cells were observed in 2015 when ponding depths were monitored. This means that all of the stormwater intercepted by the bioretention areas passed through the filter media. Surface ponding coincided with precipitation of more than 2.5 mm during the 10 minute recording interval. Ponded water infiltrated into the media quickly (less than an hour after the high intensity rainfall period).

Water levels in two of the bioretention cells were monitored in 2015. Water levels did rise above the elevation of the underdrain invert in Cell 6. The storage below the underdrain in this cell became saturated on dates that coincided with outflows at the downstream monitoring manhole. The lower portion of the storage below the underdrain in Cell 6 remained saturated between events, reducing the available storage capacity of the system. However, the trench may have intercepted a higher hydraulic conductivity unit or pathway just below the underdrain as exfiltration from this portion of the storage layer seemed to occur. In contrast, water levels drop to more than 2.0 m below ground surface between events within bioretention Cell 4, and water levels never reached the underdrain elevation in 2015.

Even with the saturated storage layer in Cell 6, the design is successful in achieving substantial volume reductions, with the associated benefits for water quality and erosion control. The monitoring shows that the design is performing better than expected with respect to peak flow reductions as well. If the native soils have very low hydraulic conductivity as is the case at Elm Drive, providing additional storage depth below the underdrain, may not be beneficial. However, it is difficult to know where fractures or higher hydraulic conductivity pathways may occur. An alternative is to place the underdrain lower but control outflow. This provides the opportunity to take advantage of exfiltration if it can occur, but have the ability to provide drainage if necessary.

5.3 Maintenance

Ponding was observed even for some relatively low intensity events. The surface infiltration capacity of the cells should be measured and maintenance performed if necessary. This will ensure that overflows continue to be infrequent.

Similarly the surface infiltration capacity of the permeable pavement should be measured and maintenance performed if necessary. See **Appendix F** for past infiltration analysis.

6 CONCLUSIONS

The Elm Drive Retrofit demonstrated the use of low impact development (LID) within the municipal right-of-way along a mixed use street. The retrofit included permeable pavement parking lay-bys, which receive runoff from the street and bioretention cells which receive excess water from the permeable pavement system. Runoff which is not retained by the LID systems through infiltration or evapotranspiration discharges to the municipal sewer. This report focused on analysis of monitoring data collected between 2011 and September 2015.

6.1 Water Quantity

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.

Elm Drive's design priorities were to provide enhanced water quality treatment and erosion control; however, the storage volume is estimated to improve pre-retrofit conditions. Monitoring has shown that Elm Drive is performing beyond expectations:

- The volume reduction achieved for events up to 25 mm in magnitude was 93 per cent; for events larger than 30 mm a 59 per cent volume reduction was achieved.
- The overall runoff volume reduction (for all events) achieved by the green street was 80 per cent.
- For the extreme event that occurred on July 8, 2013, a peak flow reduction of 40 to 60 per cent was estimated.
- Peak flows from the system were below the simulated pre-development peak flows for design events, out-performing the design estimations. 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 fifteen other events larger than the estimated 2 yr return period (33 mm), peak flow reductions ranging from 66 to 95 per cent were achieved.
- Lag times between peak rainfall and peak outflow from the system were highly variable and strongly dependent on the rainfall distribution. These findings support the ability of LID systems to provide resilience.
- For the fifteen events with magnitudes larger than 33 mm, at least 24 mm were retained (i.e. did not appear as measured outflow), exceeding CVC's stormwater management erosion control criteria to detain 5 mm on site.

6.2 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 total suspended solids (TSS) removal). The retrofit achieved 88 per cent load reduction of TSS. More than 85 per cent load removal was achieved for all parameters except nitrogen in the form of nitrate and nitrite, for which 60% load removal was achieved.

With the exception of nitrogen in the form of nitrate and nitrite, the median concentration of nutrients in the effluent from the Elm Drive site was lower than the median concentrations from sites in the International Stormwater Management Practices Database. The median concentrations of total suspended solids and the metals except iron and nickel were higher than those in the International Stormwater Management Practices Database. The time series plots suggest that total suspended solids and metals concentrations were lower early in the monitoring program.

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 waterbody.

6.3 Next Steps

1. **Long term assessment goals:** The existing databases contain insufficient information to provide answers to long term performance and maintenance questions. Most of the studies included in the databases were monitored for two to five years. However, for infrastructure life-cycle cost estimates, lifetime performance, and long-term maintenance, assessment over longer time period is required. Therefore, it is important to pool resources in extending the infrastructure assessment at Elm Drive and using the findings of this study to answer long-term questions on performance and maintenance of treatment train LID practices.
2. **Infiltration and inflow:** 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. At Elm Drive, degree of 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. The volume reduction achieved by the system reduces the amount of direct inflow volume to the municipal system, in turn decreasing the rapid impact to the collection system.
3. **Chloride contamination:** While LID practices have been implemented for several years, studies regarding LID performance in Ontario, including infiltration and chloride or salt contamination, are limited. Many LID features, such as the bioretention cells at Elm Drive, accept runoff containing a potentially high chloride concentration. Continued field monitoring throughout winter months is required to further evaluate the effectiveness of LID and the implications for the surrounding area.

7 ACCOMPLISHMENTS

MOECC's Showcasing Water Innovation and Infrastructure Performance and Asset Management programs along with over 40 private and public partners provided funding and support for the implementation of nine LID demonstration sites in Mississauga, including the Elm Drive road right-of-way LID facility. With this funding, CVC has also implemented the LID Infrastructure Performance and Risk Assessment (IPRA) program. The IPRA program provides evaluation of LID effectiveness in flood control, erosion protection, nutrient removal, and maintaining pre-development water balance. This program is producing performance data that addresses the outstanding knowledge gaps and priority stakeholder objectives identified by multiple stakeholders within CVC's 2012 SWM Monitoring Strategy.

Through Showcasing Water Innovation, CVC and its partners are being recognized provincially and internationally as a leader in LID. Local manufacturers are gaining profile and helping to build Ontario's local green economy through job creation in public and private sectors, while protecting our Great Lakes.

Sustaining the long-term quality of the Great Lakes is important because they support 40 per cent of our national economic activity and are the source of drinking water for 8.5 million Canadians (EC, 2013). CVC's comprehensive monitoring results of "in the ground" sites, tools and "How To" guides will provide municipalities, agencies and professionals with the necessary information to make LID techniques mainstream. Widespread use of LID techniques has the potential to make a major contribution to the achievement of sustainable ecosystem health, not only in the Great Lakes but in the local ecosystems of tributary watersheds.

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ELM DRIVE, CITY OF MISSISSAUGA

LOW IMPACT DEVELOPMENT INFRASTRUCTURE PERFORMANCE AND RISK MANAGEMENT ASSESSMENT

Appendix A
Monitoring Plan

NOTICE

Credit Valley Conservation Proposal: Monitoring of a Low Impact Green Road Retrofit Project

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BACKGROUND

Municipalities across Canada are struggling to address a number of issues, from aging infrastructure to insufficient stormwater management, to prevent the degradation of receiving streams and the Great Lakes, and damage to property and infrastructure from erosion and flooding.

The purpose of the study is to evaluate the effectiveness of bioretention trenches, with respect to: catchment hydrology, surface water quality, and hydrogeology. This project will help educate urban municipalities on how to balance growth, redevelopment, stormwater infrastructure, and the environment in light of climate change; providing a template that municipalities can employ to cost-effectively address environmental and development issues.

PROJECT DELIVERABLES

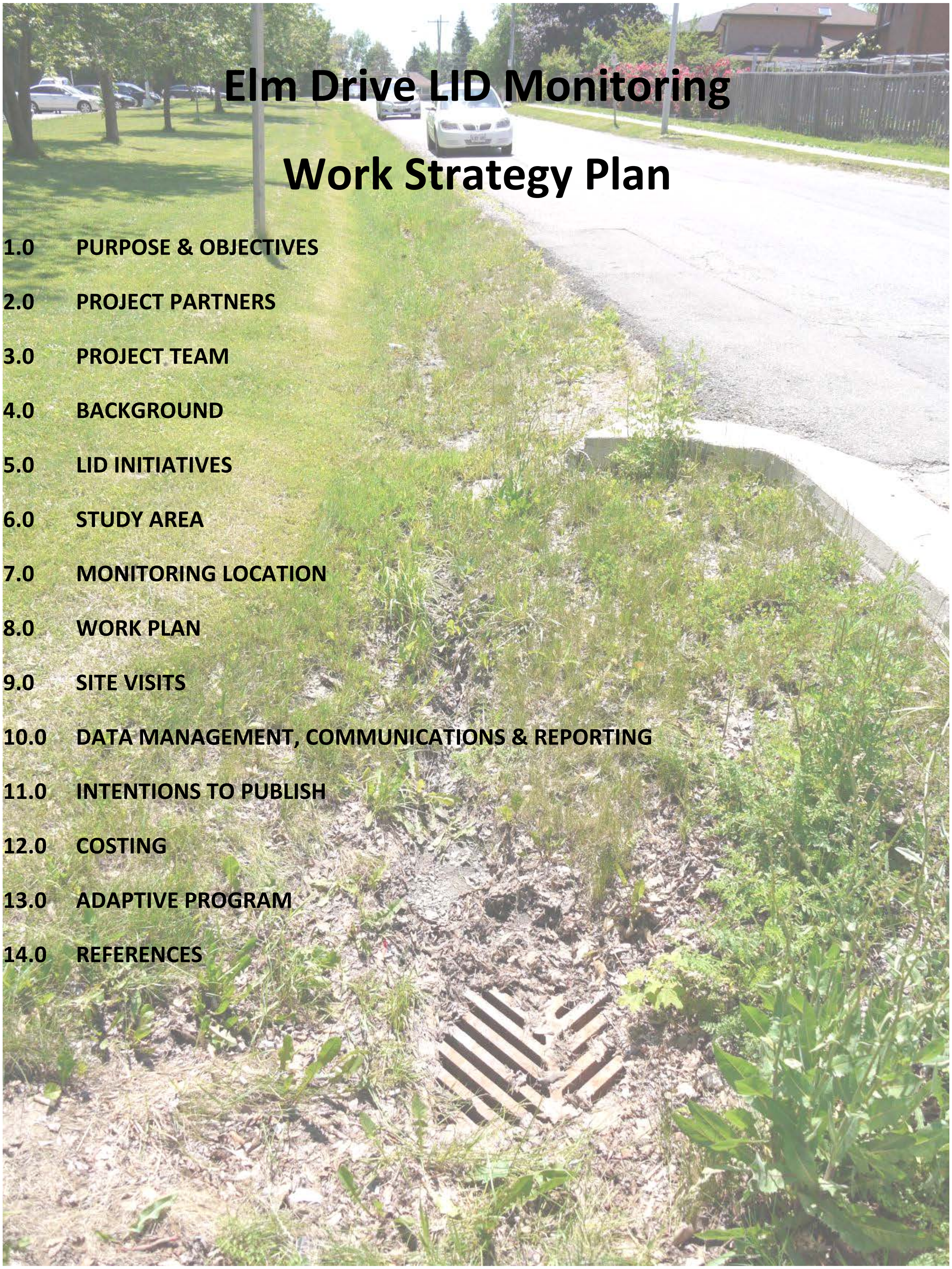
1. To support initiatives such as source protection and municipal stormwater management in light of climate change.

2. “Innovative” stormwater management demonstration site
   This stormwater treatment approach is “above and beyond” the standard practices in place pertaining to stormwater management in Ontario, using bioretention trenches as source control for innovative stormwater treatment and management. There is also little performance data currently available to support design initiatives of such practices.

3. Template for Municipalities Across Ontario
   Comprehensive effectiveness monitoring of performance data will be conducted to provide municipalities across Ontario with a template for LID implementation.

PROJECT SCHEDULE

1. Initiation of Environmental Monitoring – Spring 2011
2. End of Project – Late Fall 2016



Elm Drive LID Monitoring

Work Strategy Plan

1. Monitoring Purpose and Objectives

The purpose of the study is to evaluate the effectiveness of bioretention trenches as alternatives to roadside catch basins in dealing with storm water runoff in urban areas, with respect to catchment hydrology, water quality, and hydrogeology.

Objectives/Targets:

<u>Water Quantity</u>

- Monitoring data will be used to calibrate the models used for designing the LID applications. The models will then be rerun to determine how realistic they were in estimating the runoff volumes for the various design storms.
    - Post 2 yr = 87m^3, Post 5 yr = 143m^3, Post 10yr =195m^3, Post 25yr = 235m^3, Post 50yr =275m^3 and Post 100 yr=316m^3
- Determine the groundwater infiltration rate from the Bioswales.

<u>Water Quality</u>

- The bioretention gardens have been designed to provide Enhanced treatment per MOE guidelines.
    - Monitoring to confirm that 80% of TSS is removed from the stormwater produced from the LID Measures on an average annual basis.

This monitoring plan is based on the protocols and practices being used in other CVC monitoring programs.

2. Project Partners

1. City of Mississauga
2. Peel Board of Education
3. The Ministry of the Environment
4. Credit Valley Conservation Authority (CVC)

3. Project Team

- City of Mississauga Staff, Transportation & Works, City of Mississauga

- Christine Zimmer, Senior Water Resources Engineer, CVC
- Jennifer Dougherty, Water Quality Engineer, CVC
- Amanjot Singh, Water Quality Engineer, CVC
- Phil James, Water Resources Engineer, CVC
- Neelam Gupta, Water Resources Engineer - Hydrology, CVC
- Robb Lukes, Water Resources Specialist, CVC
- Andrew O'Rourke, Water Resources Specialist, CVC

4. Background

Our communities are supported by functions provided by our environment such as abundant, safe drinking water, and clean air. Studies conducted on the Credit River Watershed have found that we need to integrate how we build our communities with how we manage our stormwater to support a sustainable environment. This is known as Low Impact Development (LID). The planned design for the Elm Street West retrofit includes LID measures such as, biofilters, rain gardens and permeable paving stones, which will help to reduce environmental impact.

Since LID attempts to mimic natural processes, its performance depends on local conditions including, climate, soils, and drainage. Individual LID measures should be examined with respect to basic hydrological cycle components: evapotranspiration, infiltration, and runoff. Stormwater infiltration occurs on natural soils with pervious cover and at special facilities (bioretention and swales) located throughout the catchment area. At the Elm Street site, it is expected that infiltration will occur in the bioretention areas (bioswales and rain gardens). Long-term sustainable infiltration depends on soil cover, soils, hydrology, risk of clogging of infiltration sites, and infiltration facility maintenance. The process of maintaining a water balance as close to the natural state as possible also supports the enhancement of runoff quality and ecological integrity in receiving streams (J. Marsalek and Q. Rochfort 2008). CVC will be working with Mississauga Staff to assess if the LID practices put in place do indeed lead to a more natural site hydrology and water quality than in conventional stormwater management practices.

This monitoring project can act as a model to other sites contemplating bio-retention systems and a point of comparison to other locations with similar systems already in place.

This partnership research project would support the vision, goals, and objectives of Mississauga's Strategic Plan "Our Future Mississauga" by ensuring the health and attractiveness of Mississauga's communities, natural environments, and drinking water supply would be improved by encouraging and supporting alternative stormwater drainage strategies. This is also consistent with the vision of "Our Future Mississauga" - "As an environmentally responsible community, the City of Mississauga is committed to environmental protection, conducting its corporate operations in an environmentally responsible manner and promoting awareness of environmental policies, issues, and initiatives." This project sets an excellent example for the residents and businesses of Mississauga that everyone has a role to play in helping to protect and enhance the land, air, water that is enjoyed by all in Mississauga.

5. LID Initiatives

The most commonly used method of stormwater drainage in urban areas is curb and gutter. It is a very effective method for draining stormwater from neighbourhoods; however, it may be too effective. With curb and gutter drainage, storm water is quickly brought to receiving watercourses in impervious pipes. Very little of the water therefore soaks into the ground to be naturally filtered before it reaches these watercourses. This can lead to a number of problems in local streams including flash flooding, a decline water quality, and a reduction of stream baseflow and groundwater levels. Through a combination of swale drainage, biofilters, rain gardens and permeable paving stones, the hydrology and water quality leaving the Elm Street site will be improved over conventional stormwater practices.

- **Swale drainage** can reduce pollutant and sediment concentrations, and can have significant reduction time of flow to local creeks and storm drain systems. Open drainage also has the ability to reduce mosquito breeding areas through the reduction of areas with standing water (catchbasins).
- **Biofilters** or **bioretention cells** are a stormwater management technique that uses the chemical, biological, and physical properties of plants and soils to treat stormwater runoff. They are designed to mimic natural conditions promoting infiltration, retention, and the slow release of stormwater runoff.
- **Permeable Paving Stones** are an alternative to traditional impervious pavement, allow stormwater to drain through them and into a stone reservoir where it is infiltrated into the underlying native soil or temporarily detained.

6. Study Area

The subject site for the study is located in the City of Mississauga, within the Cooksville Creek watershed, and drain directly to Cooksville Creek (Figure 1). It includes Elm Street West between Joan Drive and Karlya Drive (Figure 2).

Preconstruction stormwater drainage for this roadway was served by a combination of grass swales and catchbasins with internal storm sewers, which drain directly to Cooksville Creek. A manhole was installed during construction at the end of the treatment train for monitoring purposes (Figure 2). Since the manhole will drain a specific area, it will be possible to equip it with monitoring equipment to measure flow and take water samples during rainfall or snowmelt events. A rain gauge will be installed at the site to provide precipitation data.

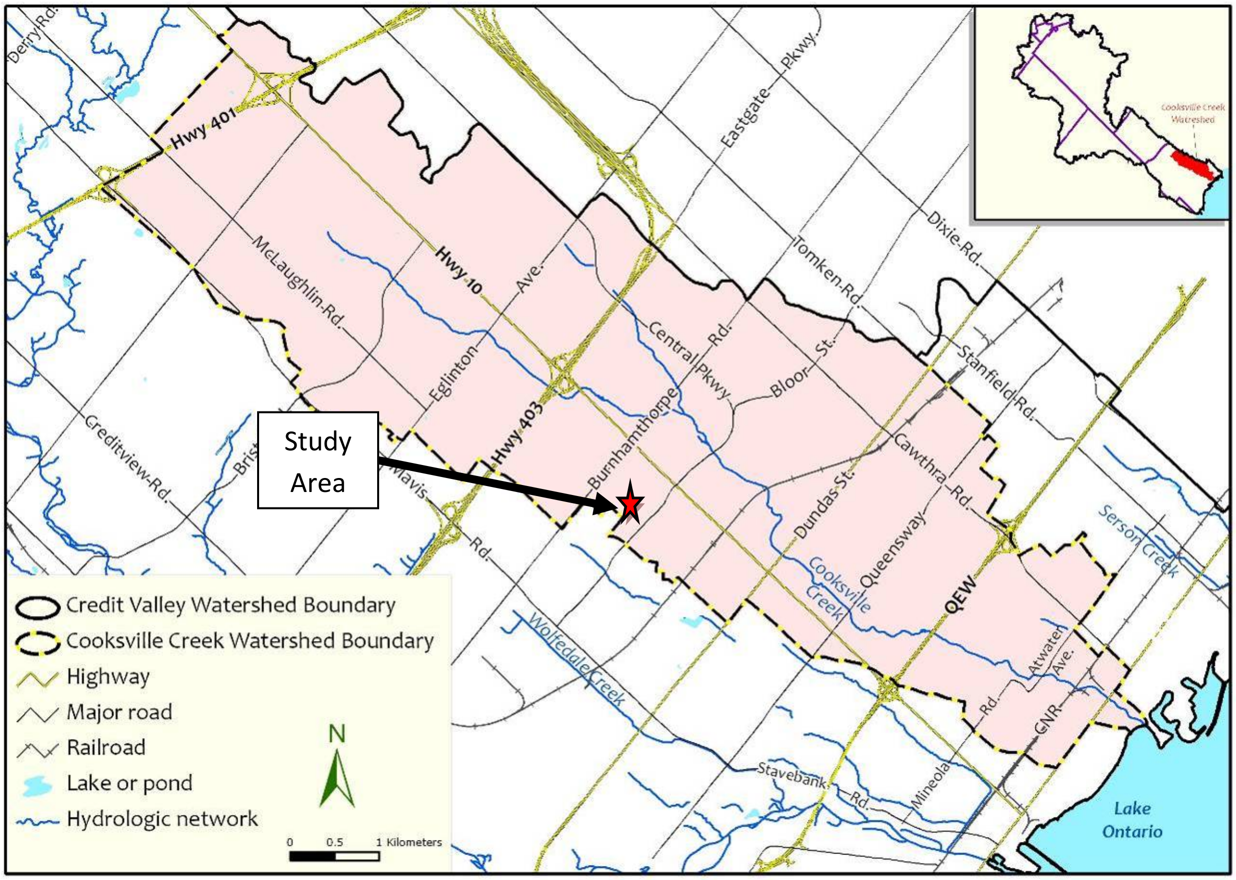


Figure 1: Study area located in the Cooksville Creek Watershed

Figure 2: Areal View of Project Area

7. Monitoring Location

Existing site plans were reviewed followed by a site walk to gain an understanding of the existing drainage system for the study area. One monitoring station is proposed for this project. During construction, a manhole was installed at the end of the treatment train for monitoring purposes. An automatic water sampler and water level logger will be installed in the manhole. Figure 3 shows an external and internal view of the manhole.

Figure 3. Monitoring station.

8. Work Plan

8.1 Hydrology

A flume or weir will be installed in the manhole located at the end of the treatment train. An ISCO 4150 or equivalent flow meter will be installed in the manhole with the probe secured to the weir to ensure accurate water level measurements. The flow meter will be set to record water levels at 10-minute intervals. In addition, a heated rain gauge will be installed close to the site to record precipitation and will be set to record at 10-minute intervals.

8.2 Surface Water Quality

A minimum of ten (10) precipitation events will be sampled per year from the monitoring location with an ISCO 6712 Automatic sampler or equivalent. The sampler will be connected to the water flow logger and triggered when a predetermined water level is recorded by the flow logger. A wet event will be defined as any rainfall event greater than 10 mm or snowfall event greater than 5 cm. The monitoring program will continue until thirty (30) precipitation events have been collected.

The sampler holds twenty-four (24) one (1) litre bottles. Samples will be analysed 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
- PAH (only 5 events, June-July)
- E.Coli Bacteria (only 5 events, June-July)
- Oil & Grease (only 5 events, June-July)

Event sampling will be conducted as follows:

- Two (2) samples will be submitted per surface water quality monitoring station per event.
- 1 initial first flush grab sample will be collected in the samplers first 6 bottles and submitted for analysis.
- The remaining 18 bottles will be used to collect a flow weighted composite sample. 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 to program in order to get a sample that best represents the event. An example program is given below.
    - The remaining 18 bottles will be filled 500 mL every 10 minutes. Therefore, 1 bottle will be filled every 20 minutes and the program will last for 6 hours.
- The 18 bottles will then be mixed into 1 flow weighted composite sample and submitted for analysis.
- Water quality samples will be brought to an accredited Canadian Laboratory for laboratory analysis.

8.3 Surface Water Infiltration

Three piezometers were installed in the bioretention cells during construction. Continuous water level loggers will be placed in the piezometers to measure water level. Level readings will then be compared to rainfall amounts to calculate surface water infiltration in the cells.

A HOBO U20 or equivalent continuous water level logger will be placed in each of the piezometers to measure water level. An additional logger will be placed at one of the locations, at the top of the piezometer above the water level, to record barometric pressure. Barometric measurements will be used to correct the water level measurements for barometric pressure. All loggers will be set to record at 10 minute intervals. Water Level readings will then be compared to rainfall amounts to calculate surface water infiltration in the bioretention cells. In addition, it will be possible to determine the drawdown time for stormwater to fully infiltrate into the rain gardens and the cells.

9. Site Visits

The site will be visited at a minimum of every two weeks to check battery power, inspect equipment, and make sure everything is operational. Data will downloaded either remotely or in person from each piece of equipment biweekly as a minimum using ISCO Flowlink 5 or Hoboware software (or equivalent). The software will automatically summarize and plot the data graphically, which can then easily be exported to a program like Microsoft Excel.

10. Data Management, Communication Strategy, & Reporting

CVC will manage water flow, water level and water quality data sets, and provide data analysis for the study. Regular updates of data can be provided to Peel Board of Education staff in Excel format for use in The Board's educational programming. CVC will coordinate with the City of Mississauga to develop a public information strategy and identify information to communicate to the public. CVC will also coordinate with Mississauga and the Peel Board in the development of interpretive signage and its erection at the study site. CVC will develop a draft report outline, author a draft report for review by the City of Mississauga, and submit a final report detailing the entire study and results.

11. Intentions to Publish

CVC and Mississauga will discuss the results and their implications. While the study is underway, information collected is confidential and not to be shared with personnel outside the study team. Once the monitoring data has undergone a thorough internal review, the intention is for the information to enter into the public domain.

12. Costing

A table outlining monitoring costs for the research project is summarized in appendix 1.

The cost estimate provides the following breakdown:

- Cost to purchase equipment;
- Cost of Equipment installation;
- Cost to Trigger samplers and collect samples;
- Cost of monthly data acquisition, equipment maintenance and calibration;
- Cost of Laboratory Analysis.

These costs are based on hiring a consultant to install the equipment. Since the equipment will be installed within the manholes, personnel certified in confined space entry will be required. In addition, staff may need to trigger and collect samples outside of typical business hours as precipitation events may occur during evenings and weekends.

13. Adaptive Program

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

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ELM DRIVE, 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.

1 SITE DESIGN AND PHYSICAL LAYOUT

During construction a manhole was installed downstream of the treatment train for monitoring purposes. Since the manhole is downstream of the facility, it is ideally located to characterize the overall performance of the system 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 deep bioretention trenches like Elm Drive are a viable method of adding resilience to urbanized areas where little stormwater management control currently exists.

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

A weir has been installed in the manhole located at the end of the treatment train. The weir is a custom compound weir by Thompson Flow Investigations. The lowest measurable flow is 0.008 L/s[1]. 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 has been installed in the manhole 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. The monitoring station is 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). Observation wells were installed in three of the bioretention cells; two of the wells were equipped with a level logger to continuously record water level in the treatment train.

A heated tipping bucket rain gauge was installed on site on the roof of Adult Education Centre to provide precipitation data. Since the rain gauge has been installed on a rooftop the likelihood that the gauge will be subjected to higher winds during more severe storm events is greater. 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 or flow 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

2.2 Surface Water Quality

CVC's surface water quality sampling goal is to sample a minimum of 10 precipitation events per year from the monitoring location with an ISCO 6712 automatic sampler. The sampler is connected to the flow logger and triggers when the flow logger records a predetermined water level. A temperature probe has also been installed in a catchbasin inlet to measure influent temperature and compare it with temperature in the outflow manhole. 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 and load analysis.

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, 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 closely monitoring autosamplers or manual sampling and quick transport of iced samples to laboratory.
- Oil & Grease--This parameter has been 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), or the Ministry of Environment and Climate Change lab, for analysis. Table 2-1 summarizes water quality parameters, analytical methods and associated method detection limits (MDLs).

Figure 2-1: Typical sampling turbidity at a curb and gutter site

Figure 2-2:Typical sampling turbidity at Elm Drive

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	0.02-0.004[4]
Escherichia coli (E. coli)[3]	CFU/100mL	MOE LSB E3371	10
Total Suspended Solids (TSS)	mg/L	SM 2540D	1

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

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

3 Monitoring 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 in the three of the bioretention cells during construction. HOBO U20 water level loggers have been placed in two of the piezometers to measure water levels. An additional logger has been placed at one of the locations above the water level 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 then 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.

Surface water infiltration tests were conducted in fall 2013. A Guelph Permeameter was used to measure the infiltration rate of the bioretention cell filter media. Constant head permeability testing with the Guelph permeameter was conducted on unsaturated filter media. The tests were conducted until steady state flow (saturated hydraulic conductivity) was achieved. Detailed steps for field tests and analysis were completed by following the Guelph Permeameter Operating Instructions provided by Soilmoisture Equipment Corp. The facility passes infiltration testing when the in-situ infiltration rates are higher than the minimum threshold of 25 mm/hr. Filter media infiltration tests at were performed on October 17, 2013. Two tests were performed in cell 6 and cell 4 (four tests in total).

The infiltration rate of the permeable pavement sections (lay-bys and sidewalk) were established by following ASTM C1701. A single ring infiltrometer (300 mm diameter) was temporarily affixed to the permeable pavement with putty to create a water tight seal, preventing leakage. A known mass of water was poured into the infiltration ring while maintaining constant head. The elapsed time until there was no standing water on the permeable pavement surface was recorded. Determining the infiltration rate consists of two tests, a prewetting test and the actual infiltration test. A test was considered to fail if the prewetting test time exceeded 0.5 hr for 3.6 kg of water to infiltrate (approximately 100 mm/hr). Permeable pavement infiltration tests at were performed on November 14, 2013. Five and seven tests were performed on the lay-bys and sidewalk, respectively.

2.4 Soil Sampling

The LID approach at Elm Drive 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.

Sampling occurred October 2, 2013 and 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 Elm Drive 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

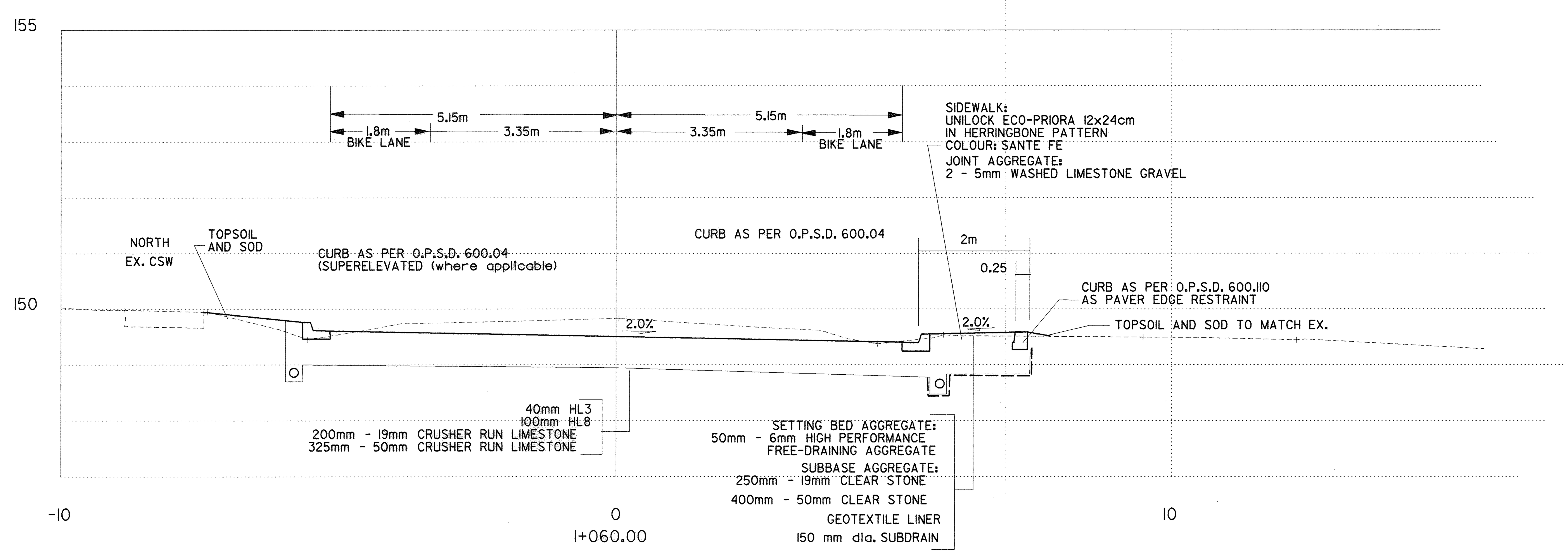
CVC staff visit the site at least once every other week to check battery power, inspect equipment, and make sure the site is operating properly. Data is downloaded either remotely or in person from each piece of equipment bi-weekly or more frequently using ISCO Flowlink 5 or Hoboware. The software will 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.

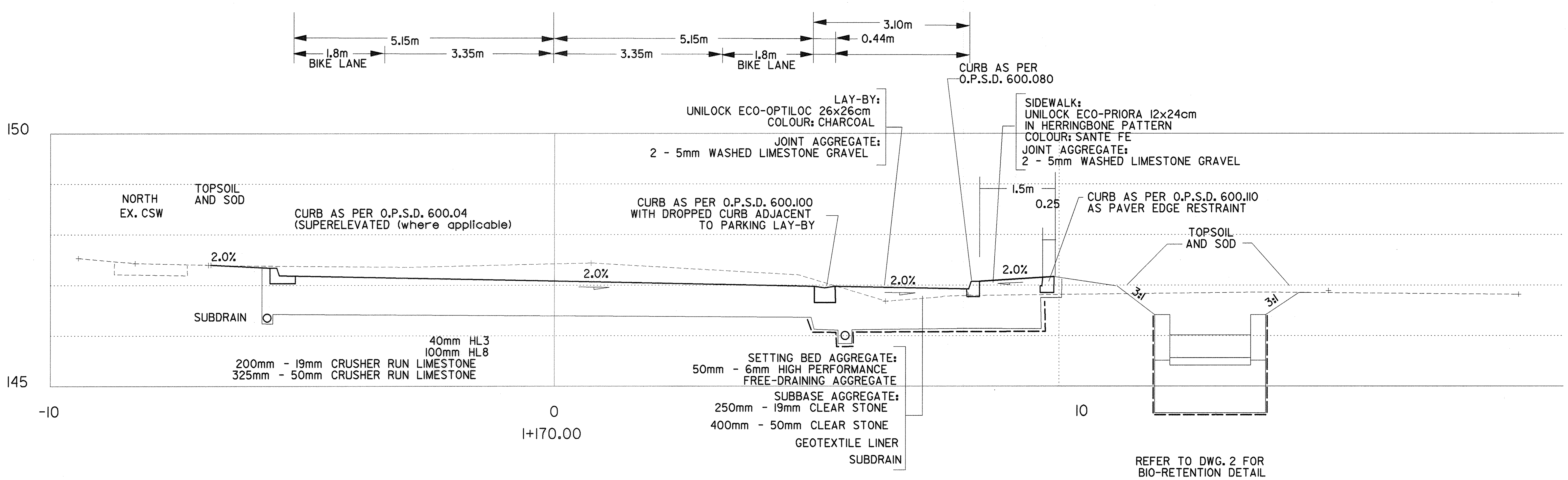
2.6 Site Maintenance

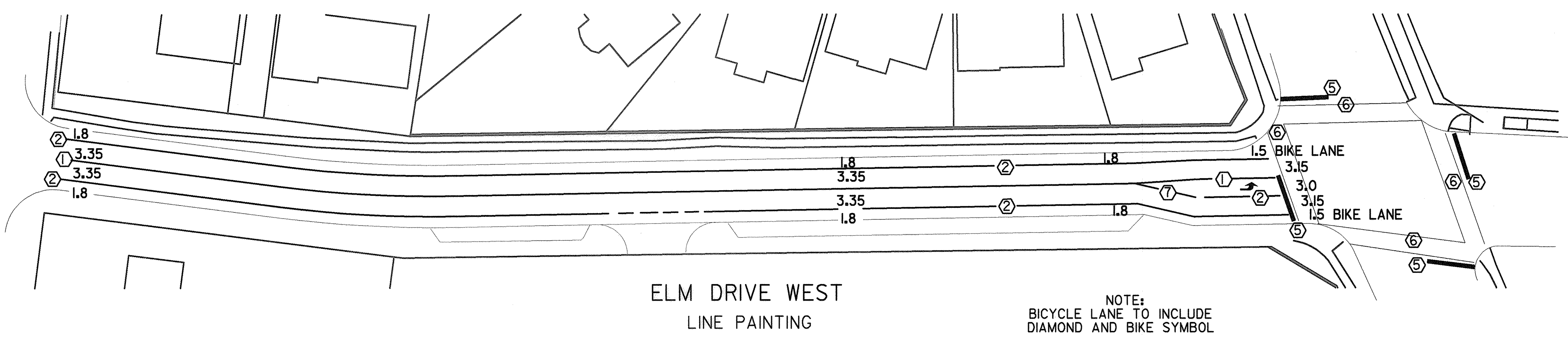
The stormwater facilities at Elm Drive are designed to trap pollutants, and assuming the permeable pavement laybys and bioretention cells are effective, pollutants including trash/gross solids, sediments and other stormwater pollutants will accumulate that will need to be removed periodically through 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 is responsible for the maintenance of this site and has an agreement with the Peel District School Board recognizing this.

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 for 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 such as filter media reaching saturation. This information in concert with cost tracking will benefit asset management information.







SERVICE DATA					
SERVICE	DATE	INIT.	SERVICE	DATE	INIT.
SAN. SEWERS	MAY,2010	K.K.	GAS MAINS	MAY,2010	K.K.
STM. SEWERS	MAY,2010	K.K.	BELL U/G CABLE		
WATERMAINS	MAY,2010	K.K.	HYDRO U/G CABLE	MAY,2010	K.K.
M.O.E.			ROGERS U/G CABLE		

REVISIONS		
DATE	DETAILS	INIT.

1. CURB, NORTH SIDE:

CURB AS PER O.P.S.D. 600.04 0+000 TO 0+012

TRANSITION 0+012 TO 0+020 TO SUPERELEVATED GUTTER

0+020 TO 0+200 SUPERELEVATED GUTTER AS PER STANDARD DETAIL

GENERAL NOTES

1. ALL DRIVEWAYS ASPHALT UNLESS OTHERWISE NOTED
2. ALL SERVICE LOCATIONS ARE APPROXIMATE AND MUST BE LOCATED ACCURATELY IN FIELD
3. ALL MEASUREMENTS FOR THIS PROJECT ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE INDICATED
4. ALL SINGLE C.B. LATERALS TO BE 250mm O ØL 65-D
   ALL OTHERS TO BE 300mm O ØL 65-D
5. ALL TREES AND SHRUBS NOT MARKED IN THE FIELD FOR REMOVAL, TO BE PROTECTED
6. ALL SEWERS AND LATERALS TO HAVE CLASS 'B' BEDDING AND SAND COVER BACKFILL UNLESS OTHERWISE INDICATED
7. ALL UTILITY RELOCATION BY OTHERS
8. "X" - DENOTES REMOVALS
9. DURING SEWER CONSTRUCTION, WATERMAINS TO BE PROTECTED TO THE SATISFACTION OF THE PUBLIC WORKS DEPARTMENT OF THE REGIONAL MUNICIPALITY OF PEEL
10. COLD GRINDS TO BE MAX. 50mm IN DEPTH UNLESS OTHERWISE NOTED
11. INFORMATION SHOWN HEREON IS FOR USE BY THE CITY OF MISSISSAUGA, TRANSPORTATION AND WORKS DEPARTMENT, AND IS NOT INTENDED FOR USE BY ANY OTHER PARTIES UNLESS EXPRESSED WRITTEN CONSENT IS OBTAINED. MEASUREMENTS SHOWN MUST BE CONFIRMED BY FIELD SURVEY BEFORE USE.
12. PROTECTED BY COPYRIGHT. MAY NOT BE REPRODUCED WITHOUT PERMISSION
13. **THIS IS NOT A PLAN OF SURVEY**

PAVEMENT MARKING SYMBOLS

(NOTE: ALL MARKINGS MUST CONFIRM TO THE M.U.T.C.D.)

PAVEMENT ARROWS (300cm X 135cm)

1. 10cm YELLOW SOLID
2. 10cm WHITE SOLID
3. 10cm WHITE SKIPS (3m LINE-9m SPACING)
4. 10cm YELLOW SKIPS (3m LINE-6m SPACING)
5. 45cm WHITE SOLID - STOP BARS
6. ZEBRA STRIPE CROSSWALK LINES
7. 10cm WHITE SKIPS (3m LINE-3m SPACING)
8. GRINDINGS
9. 10cm WHITE SKIPS (1m LINE-1m SPACING)

DESIGN BY

B. MULLIGAN C.E.T.

DEPARTMENTAL APPROVAL

EZIO SAVINI P.ENG.

APPROVED BY

LICENSED PROFESSIONAL ENGINEER
Bob Levesque
R.R.J. LEVESQUE
Aug. 5, 2010
PROVINCE OF ONTARIO

MISSISSAUGA
Leading today for tomorrow

PRODUCED FOR - T&W, ENGINEERING AND WORKS

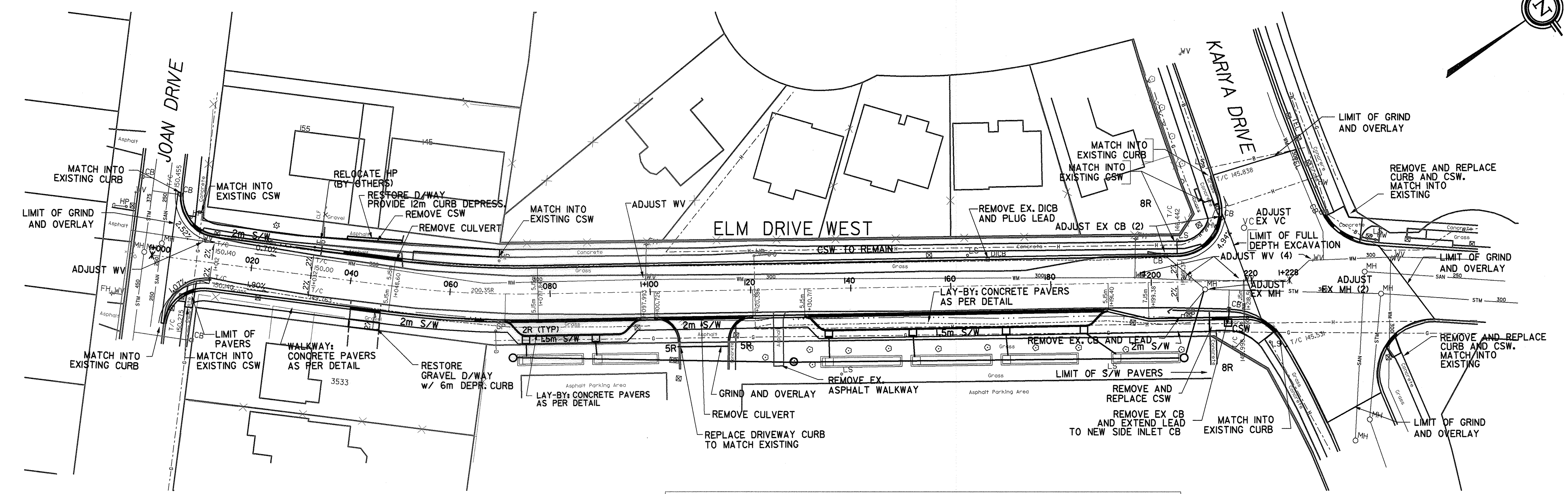
ELM DRIVE WEST
JOAN DRIVE TO KARIYA DRIVE
DETAILS

SCALE HOR. 1:500 VERT. 1:50	AREA Z-22	PROJECT No. 10-121
C.A.D.D. BY K.K.	CHECKED BY	PLAN No. C48333
DATE JUNE, 2010	SHEET 5 OF 5	

SERVICE DATA					
SERVICE	DATE	INIT.	SERVICE	DATE	INIT.
SAN. SEWERS	MAY,2010	K.K.	GAS MAINS	MAY,2010	K.K.
STM. SEWERS	MAY,2010	K.K.	BELL U/G CABLE		
WATERMAINS	MAY,2010	K.K.	HYDRO U/G CABLE	MAY,2010	K.K.
M.O.E.			ROGERS U/G CABLE		

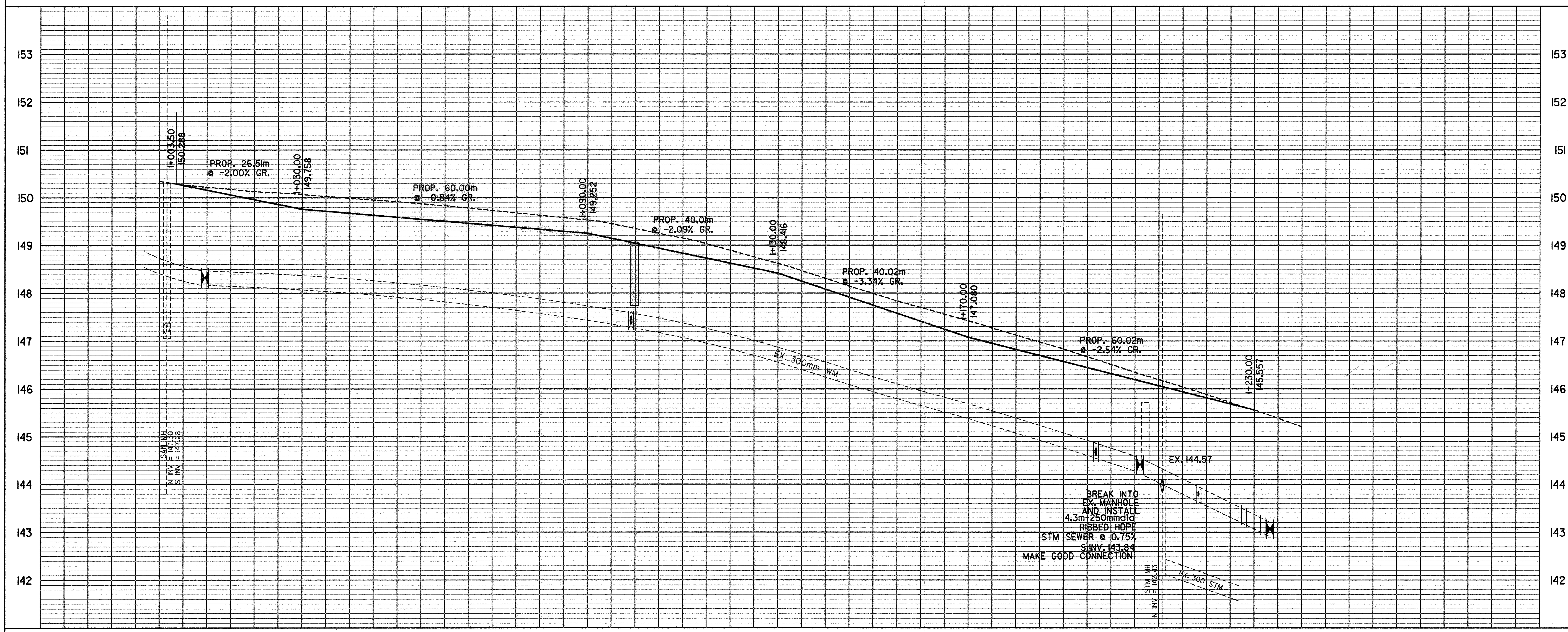
REVISIONS		
DATE	DETAILS	INIT.

NOTE:
ADDITIONAL WORKS AT INTERSECTION
TO INCLUDE THE SUPPLY AND INSTALLATION
OF 8 VEHICLE LOOPS, INCL. 7@ 1.8x9m
and 1@ 1.8 x 1.8m, LOCATED AS DIRECTED BY ENGINEER.



REFER TO
DWG. 2 FOR BOULEVARD WORKS AND DETAILS
DWG. 3 FOR BOULEVARD GRADING
DWG. 4 FOR LANDSCAPING

NOTE: THIS DRAWING (1) SUPERCEDES THE CURB LAYOUT AS SHOWN ON DWG.s 2,3 AND 4



FINAL RD. GR.		149.958	149.673	149.505	149.336	149.043	148.625	148.082	147.414	146.826	146.318	145.810	
EXIST RD. GR.	150.35	150.13	149.99	149.83	149.63	149.35	148.89	148.31	147.70	147.12	146.51	145.88	145.20
CHAINAGE	1+000.00	1+020.00	1+040.00	1+060.00	1+080.00	1+100.00	1+120.00	1+140.00	1+160.00	1+180.00	1+200.00	1+220.00	1+240.00

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DESIGN BY	APPROVED BY
B. MULLIGAN C.E.T.	LICENSED PROFESSIONAL ENGINEER R.R.J. LEVESQUE Aug. 5, 2010 PROVINCE OF ONTARIO
DEPARTMENTAL APPROVAL	
EZIO SAVINI P.ENG.	

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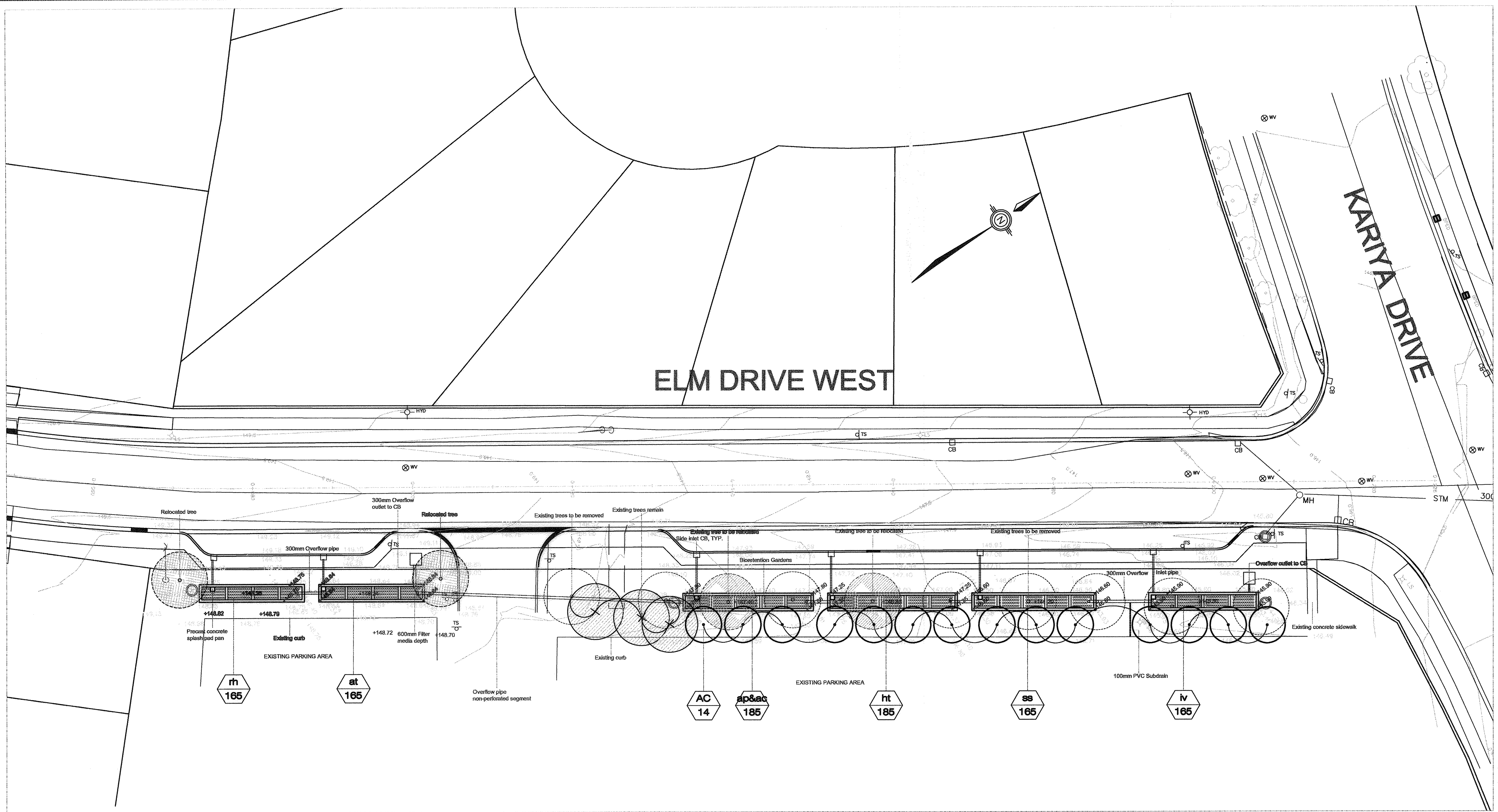
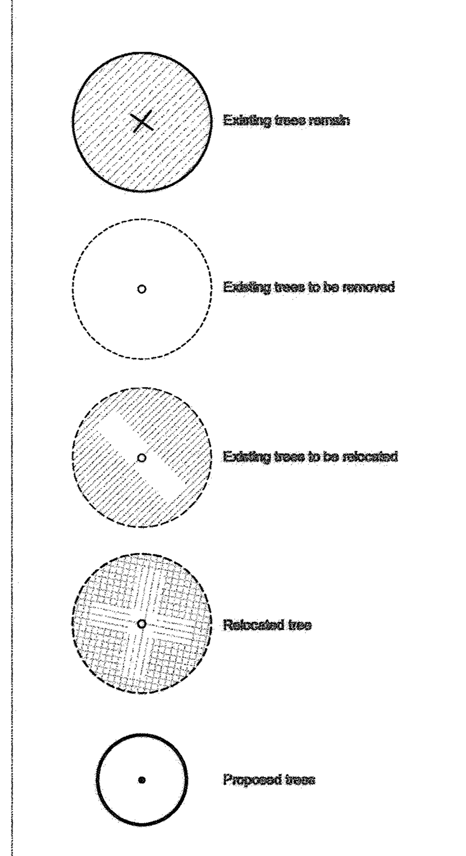
ELM DRIVE WEST
JOAN DRIVE TO KARIYA DRIVE
1+000 to 1+240

SCALE HOR. 1:500 VERT. 1:50	AREA Z-22	PROJECT No. 10-128
C.A.D.D. BY K.K.	CHECKED BY	PLAN C48329
DATE JUNE, 2010	SHEET 1 OF 5	





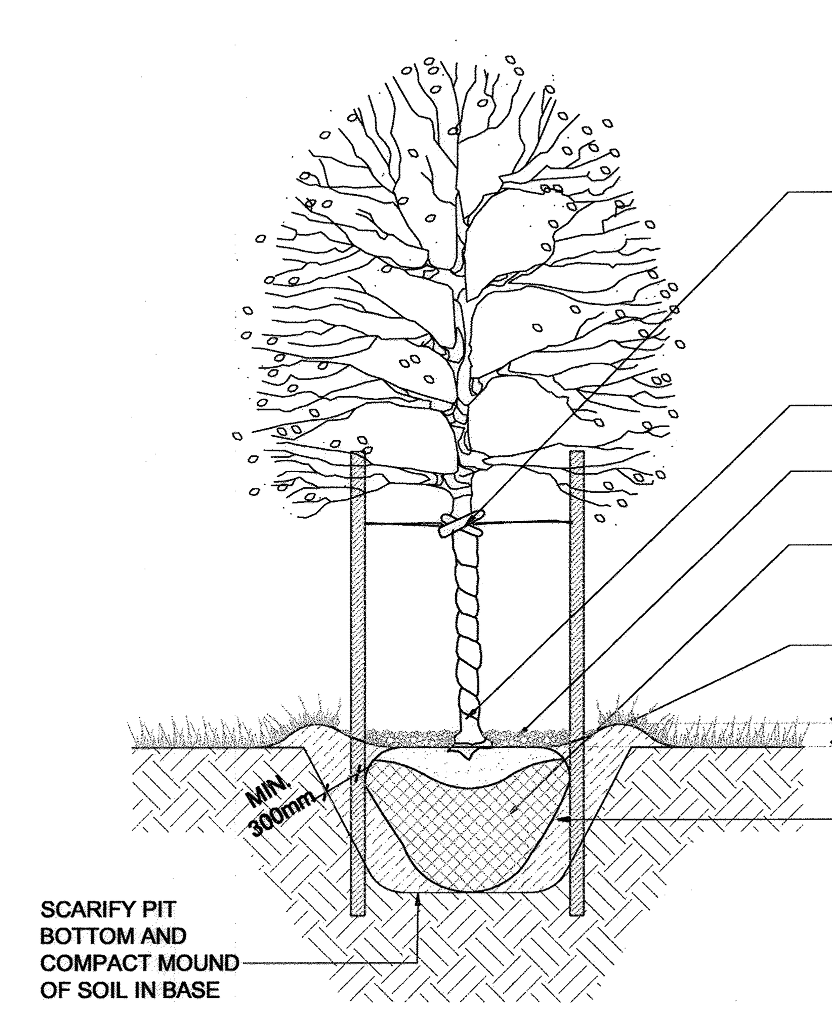
PLANT LIST

DECIDUOUS TREES

Key	Qty.	Botanical Name	Common Name	Size	Root	Remarks
AC	12	Amelanchier canadensis	Serviceberry (Multistem)	300cm	W.B.	@6-8m O.C

PERENNIALS

Key	Qty.	Botanical Name	Common Name	Size	Root	Remarks
at	165	Asclepias tuberosa	Butterfly Weed		10 cm pot	@.6 m O.C.
ap	95	Aster pilosus	White Heath Aster		10 cm pot	@.5 m O.C.
ac	90	Aster cordifolium	Heart-leaved Aster		10 cm pot	@.5 m O.C.
ht	185	Helianthus tuberosus	Jerusalem Artichoke		10 cm pot	@.5 m O.C.
iv	165	Iris versicolor	Blue Flag Iris		10 cm pot	@.5 m O.C.
rh	165	Rudbeckia hirta	Black Eyed Susan		10 cm pot	@.5 m O.C.
ss	165	Schizachyrium scoparium	Little Bluestem		10 cm pot	@.5 m O.C.



TREE PLANTINGS SHALL HAVE 2400MM LONG T-RAIL IRON STAKES 37MM X 37MM X 5MM DRIVEN 300MM BELOW ROOT BALL.

TREE STAKES TO BE REMOVED AT THE END OF THE GUARANTEE PERIOD

DO NOT DRIVE STAKE THROUGH ROOTBALL. STAKE SHALL BE DRIVEN FIRMLY INTO UNDISTURBED SOIL.

NO. 9 GALVANIZED WIRE GUYS ENCASED IN RUBBER HOSE.

TREE TIE SHALL BE FASTENED AROUND THE TREE IN A FIGURE EIGHT IN A N.W. ORIENTATION AND RUBBER HOSE AS SPECIFIED.

WRAP TREE WITH APPROVED TREE WRAP TO THE BOTTOM OF THE FIRST BRANCH.

DEPTH OF MULCH AS SPECIFIED, 100MM.

REMOVE ALL WIRE, ROPE AND BURLAP FROM THE TOP 1/3 OF ROOTBALL. SYNTHETIC BURLAP SHOULD NOT BE USED ON ROOT BALL.

FIRMLY COMPACTED SAUCER TO CREATE MINIMUM 150MM HIGH LIP AROUND TREE

PLANTING SOIL MIXTURE AS PER PLANTING SPECIFICATIONS
SET TREE HIGHER THAN ADJACENT GRADE TO ALLOW FOR SETTLEMENT.

FIRMLY COMPACT ANY BACK FILLED SOIL TO ELIMINATE AIR POCKETS AND PREVENT SOIL SETTLEMENT

PRUNE BRANCHES TO REMOVE DAMAGED OR OBJECTIONAL BRANCHES BY PROPER HORTICULTURAL PRACTICES.

1 / L500 DECIDUOUS TREE PLANTING
TYPICAL INSTALLATION FOR TREES 50mm CALIPER AND LARGER 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.

SHRUBS AND GROUND COVERS:

9. Shrubs and ground covers shall have full, well branched crowns typical of species or variety. 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 Owner 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 Owner 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.
   - Shrub Planting Beds: 500mm minimum continuous depth.
   - Tree Planting Beds: 600mm minimum continuous depth.
   - Sodded / Seeded Areas: 200mm minimum continuous depth.

4. Bioretention filter media soil mix (600mm depth):
   -Sand (2.0 to 0.05mm dia.) 85% to 88%
   -Fines (<0.05mm dia.) 8% to 12%
   -Organic matter 3% to 5%

BED PREPARATION:

Tree pits and planting beds for new trees shall be backfilled to the specified depths with:
- parts of sandy loam
- part of finely pulverized Canadian peat moss
- part of well-rotted farm manure and apply "Agriform" 20-10-5 tablets(or approved equal) to manufacture's specifications.

SERVICES, STAKEOUTS & PLANTING ADJUSTMENTS

1. Contractors shall obtain stakeouts from all Utilities prior to landscape installations. Tree and shrub pits shall not be permitted within one point five (1.5) metres of the sides or rear and three (3) metres of the front of any pad-mounted transformer, or within one (1) metre of any underground Hydro road crossing location. All excavations within one (1) metre of any buried Hydro or Gas utility shall be hand-dug. Tree or shrub pits shall not be permitted within one (1) metre of a fire hydrant. Plantings will not be permitted within a switchgear facility easement.

2. Final street tree locations (on Municipal right-of-ways) may require adjustment from Plan locations subject to as-built utilities, services, and driveway locations. The City reserves the right to request additional street tree plantings in suitable locations where as-built conditions prohibit the minimum standard for street tree plantings. Provide notice and coordinate all street tree locations with the City of Toronto Parks Division prior to planting.

TREE PLANTING IN R.O.W.

1. Tree location to be verified adjacent buried services, obtain PUCC clearance. Refer to civil engineer's plans for street level installations and locate all buried services prior to installing tree pit
2. If required, provide **pvc barrier** along vertical wall of tree pit adjacent existing buried services

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 of Toronto, 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 necassary to ensure normal, healthy growth of planted material.

Maintenance inspection of hard landscape components (i.e. unit paving, fences, walls etc.) shall be performed a minimum of once per year to ensure the integrity and safe, intended use of the landscape component. Deficiencies observed shall be documented and remedied in a timely manner.

PLANTING MAINTENANCE NOTES

FOR GENERAL SEEDED AREA:

Wild Flower and Grass Seed Mixture - Type W1
Seed type: Perennial seed to match plant species within each cell.

Seeding rate: 20kg/ha (mechanically applied) for grass seed 10-12 kg/ha (mechanically applied) for wildflower blend mix, and as specified by supplier. Refer to manufacturer's specifications for manual application rates.
Supplier: Pickseed Canada or approved equal.

SERVICE DATA

REVISIONS

KEY PLAN N.T.S.

SCHOLLEN & Company Inc.
Don Mills, Ontario
Tel: (416) 441-8044
Fax: (416) 441-8010

LEGEND
- PROPOSED SANITARY MANHOLE
- PROPOSED STORM MANHOLE
- PROPOSED CATCHBASIN
- PROPOSED DOUBLE CATCHBASIN
- PROPOSED VALVE & CHAMBER
- PROPOSED VALVE & BOX
- PROPOSED HYDRANT & VALVE
- EXISTING HYDRO POLE
- EXISTING HYDRO POLE LIGHT STANDARD
- EXISTING TRAFFIC LIGHT POLE
- EXISTING TRAFFIC LIGHT POLE/LIGHT STANDARD
- EXISTING ANCHOR POLE
- EXISTING BELL MANHOLE
- EXISTING BELL PEDESTAL
- EXISTING MANHOLE
- EXISTING WATER VALVE
- EXISTING WATER VALVE CHAMBER
- EXISTING HYDRANT
- EXISTING CATCH BASIN

The MUNICIPAL INFRASTRUCTURE Group Ltd.
Vaughan, Ontario
Tel. 905-738-5700 Fax 905-738-0065

NOTICE TO CONTRACTOR
48 HOURS PRIOR TO COMMENCING WORK NOTIFY THE FOLLOWING

HORIZONTAL SCALE

DESIGN BY | APPROVED BY

DEPARTMENTAL APPROVAL

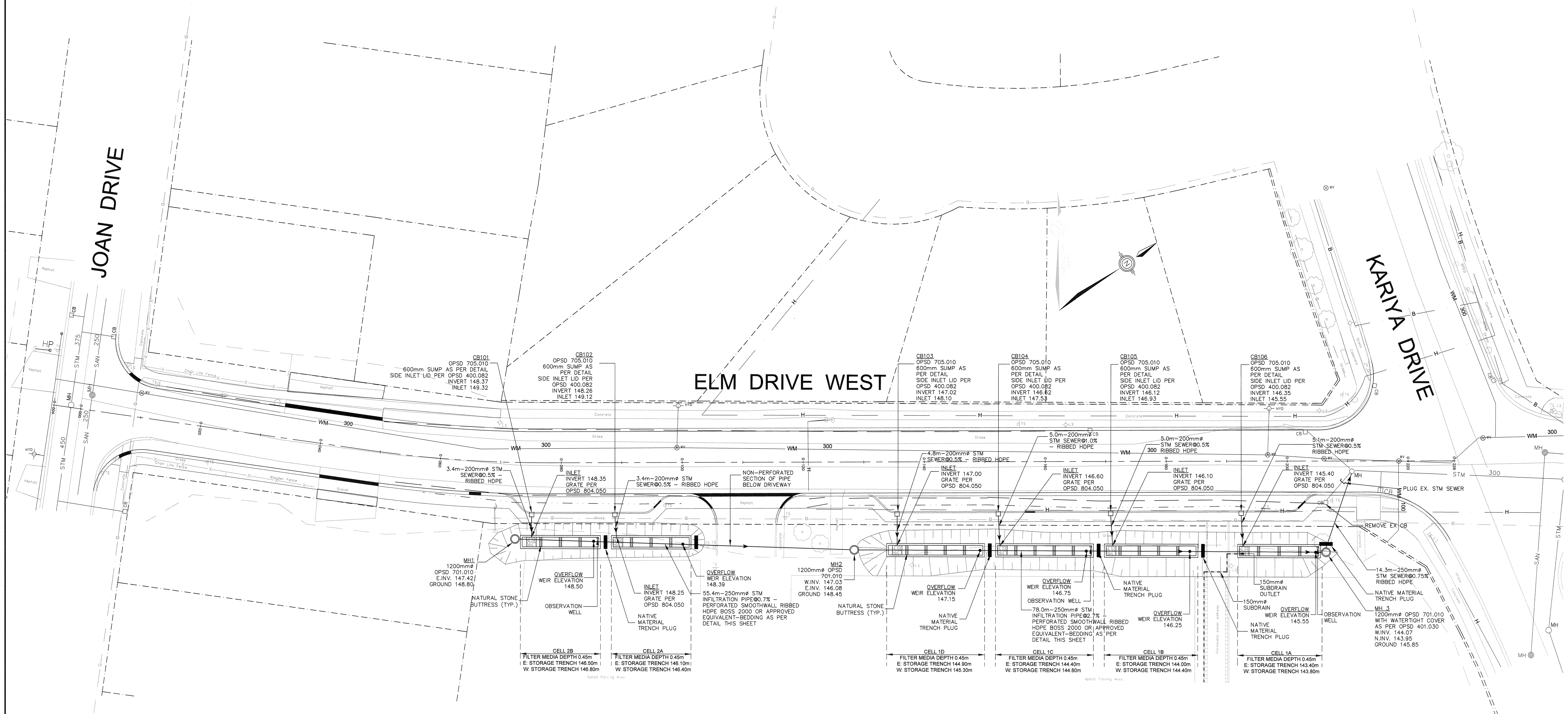
MISSISSAUGA Transportation and Works

ELM DRIVE WEST LANDSCAPE PLAN

SCALE 1:400	AREA Z-22	PROJECT No. 10-121
C.A.D.D. BY	CHECKED BY	
DATE JUNE, 2010	SHEET 4 OF 5	C48332

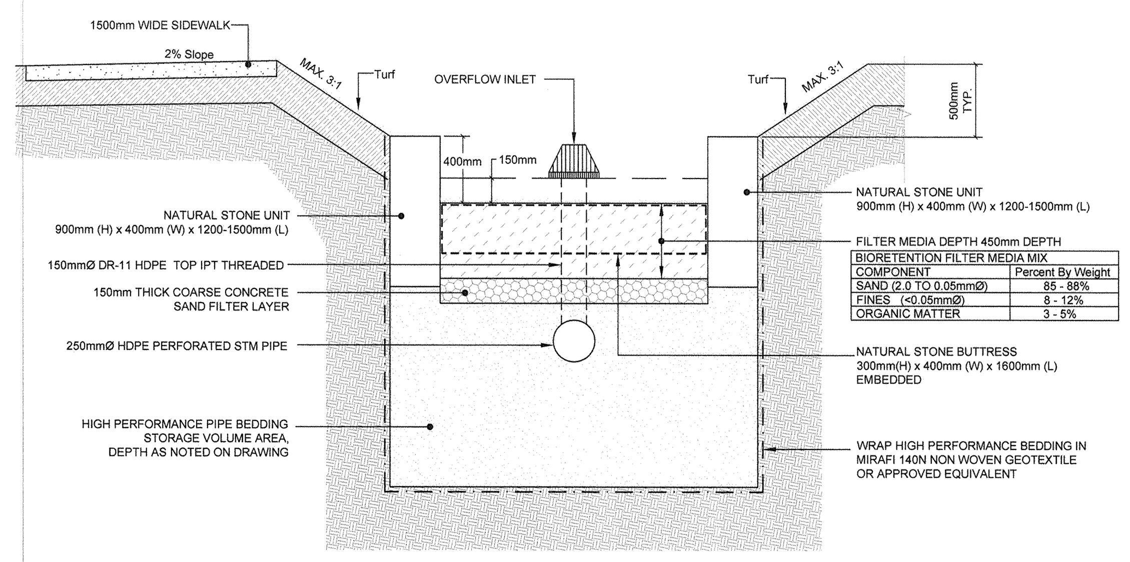
NOTE:

TO BE READ IN CONJUNCTION WITH DWG 1,
ELM DRIVE WEST PLAN & PROFILE



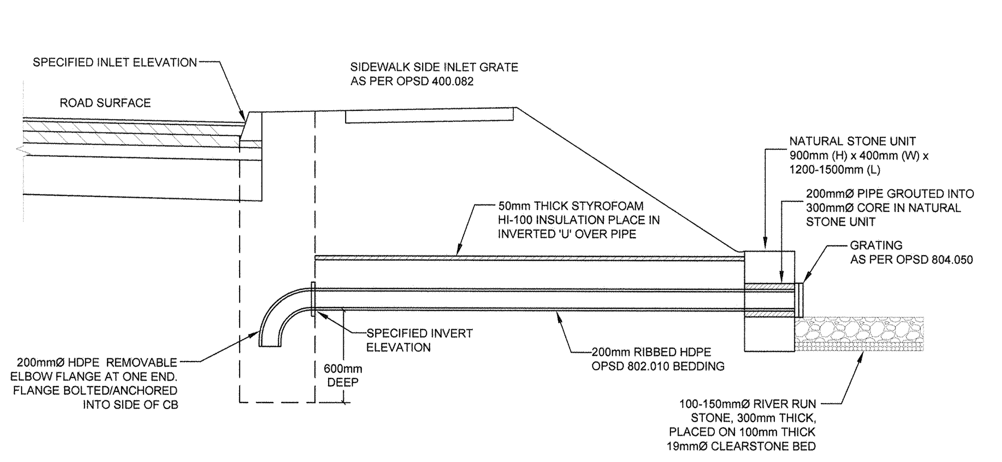
SITE SERVICING PLAN

SCALE 1:250



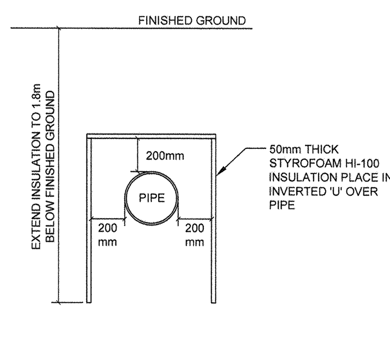
TRENCH SECTION

NTS



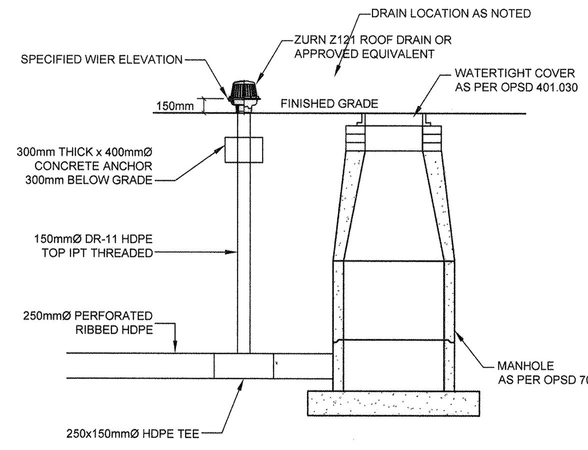
INLET SECTION

NTS



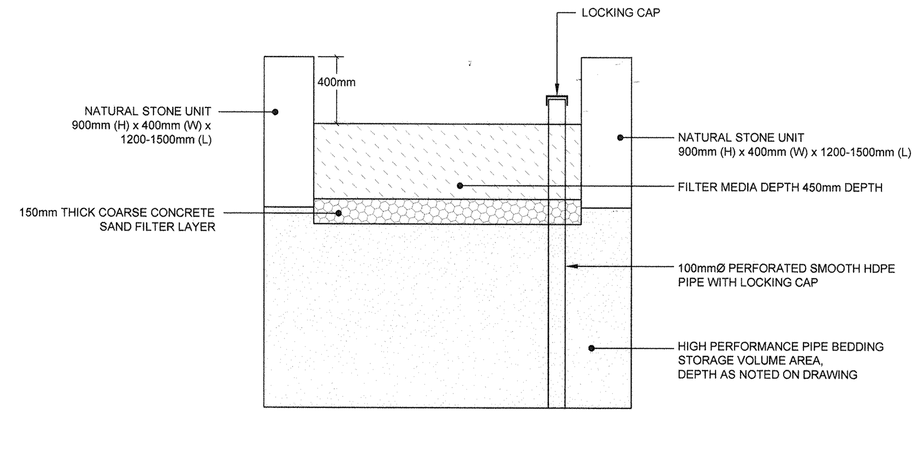
INSULATION DETAIL

NTS



MANHOLE INLET DETAIL

NTS



OBSERVATION WELL

NTS

SERVICE DATA

SERVICE	DATE	INIT.	SERVICE	DATE	INIT.
SAN SEWERS			GAS MAINS		
STORM SEWERS			BELL U/G CABLE		
WATERMAINS			HYDRO U/G CABLE		
TRANSIT			HYDRO ONE		
PARKS & REC.			CTV		
ONT. CLEAN WATER			COMMUNIC. CABLES		

REVISIONS

DATE	DETAILS	INIT.

KEY PLAN
N.T.S.

LEGEND

- PROPOSED SANITARY MANHOLE
- PROPOSED STORM MANHOLE
- PROPOSED CATCHBASIN
- PROPOSED DOUBLE CATCHBASIN
- PROPOSED VALVE & CHAMBER
- PROPOSED VALVE & BOX
- PROPOSED HYDRANT & VALVE
- EXISTING HYDRO POLE
- EXISTING HYDRO POLE LIGHT STANDARD
- EXISTING TRAFFIC LIGHT POLE
- EXISTING TRAFFIC LIGHT POLE/LIGHT STANDARD
- EXISTING ANCHOR POLE
- EXISTING BELL MANHOLE
- EXISTING BELL PEDESTAL
- EXISTING MANHOLE
- EXISTING WATER VALVE
- EXISTING WATER VALVE CHAMBER
- EXISTING HYDRANT
- EXISTING CATCH BASIN
- 100-150mmØ RIVER RUN STONE, 300mm THICK SET ON 100mm THICK 19mmØ CLEARSTONE BED.

The MUNICIPAL INFRASTRUCTURE Group Ltd.
2300 Steeles Ave. West, Suite 120
Vaughan, Ontario, L4K 5X6
Tel. 905-738-5700 Fax 905-738-0065

NOTICE TO CONTRACTOR

48 HOURS PRIOR TO COMMENCING WORK NOTIFY THE FOLLOWING

THE REGIONAL MUNICIPALITY OF PEEL
CITY OF MISSISSAUGA WORKS DEPT.
ROGERS CABLE COMMUNICATIONS
BELL CANADA
ENBRIDGE GAS DISTRIBUTION
ONTARIO MINISTRY OF TRANSPORTATION
ONTARIO CLEAN WATER AGENCY
HYDRO ONE NETWORKS
HYDRO ONE BRAMPTON

5m 0 5 10 15m HORIZONTAL SCALE

DESIGN BY

LICENSED PROFESSIONAL ENGINEER 7/28/2010 L. N. RUSSELL 100032788 PROVINCE OF ONTARIO

APPROVED BY

DEPARTMENTAL APPROVAL

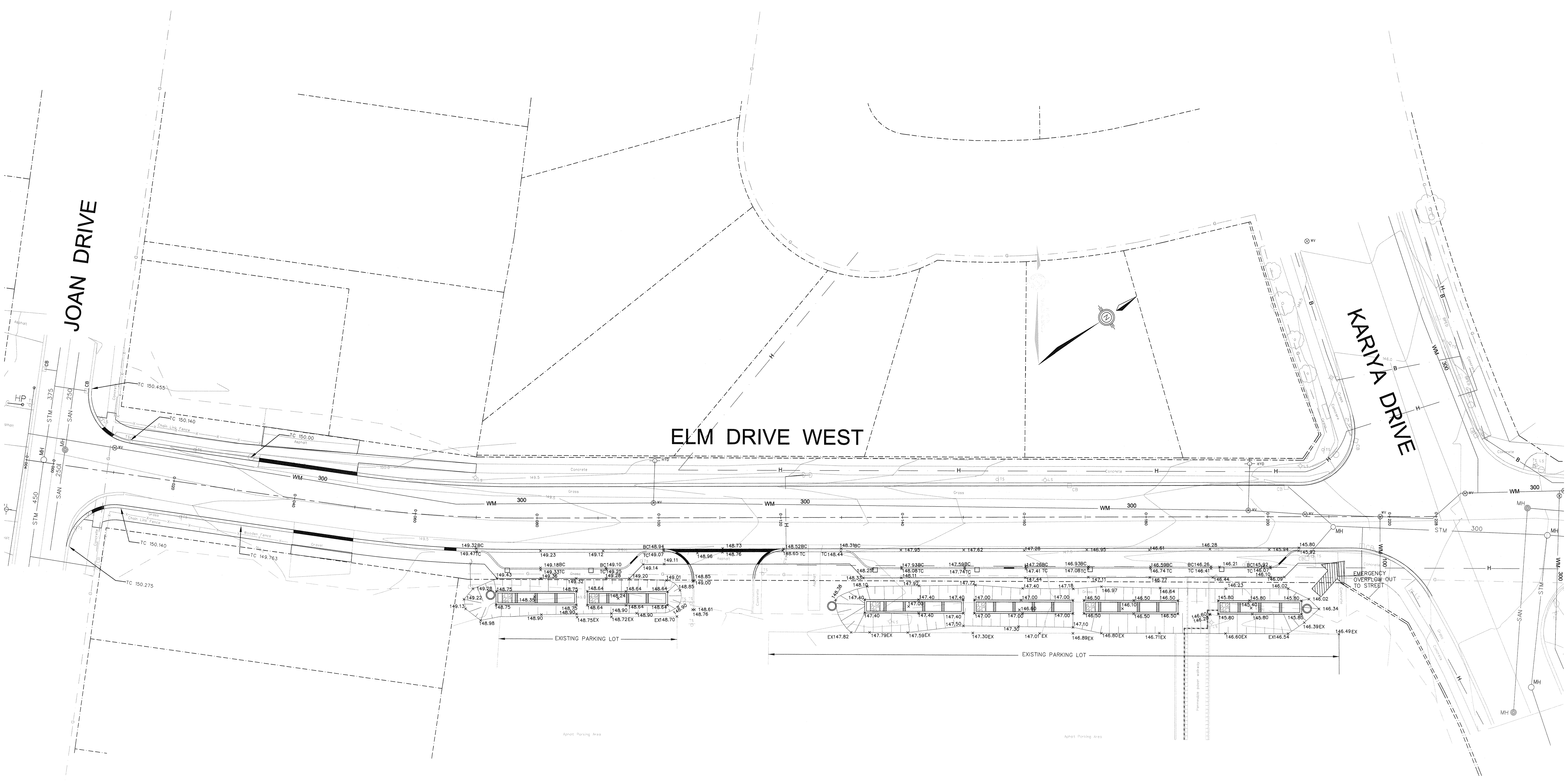
MISSISSAUGA Transportation and Works

ELM DRIVE WEST BOULEVARD SERVICING PLAN

SCALE	1:250	AREA		PROJECT No.	10121
C.A.D.D. BY:	CAD	CHECKED BY:	C.E.	PLAN No.	C48330
DATE	July 28 2010	SHEET	2 OF 5		

NOTE:

TO BE READ IN CONJUNCTION WITH DWG 1, ELM DRIVE WEST PLAN & PROFILE

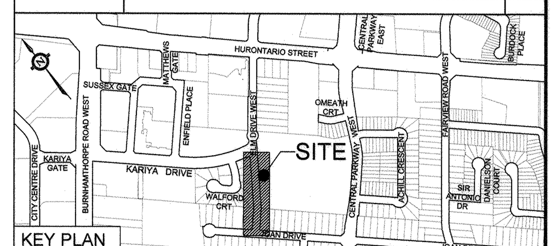


SERVICE DATA

SERVICE	DATE	INIT.	SERVICE	DATE	INIT.
SAN SEWERS			GAS MAINS		
STORM SEWERS			BELL U/G CABLE		
WATERMAINS			HYDRO U/G CABLE		
TRANSIT			HYDRO ONE		
PARKS & REC.			CTV		
ONT. CLEAN WATER			COMMUNIC. CABLES		

REVISIONS

DATE	DETAILS	INIT.
-	-	



KEY PLAN
N.T.S.

LEGEND

●	PROPOSED SANITARY MANHOLE
○	PROPOSED STORM MANHOLE
□	PROPOSED CATCHBASIN
□□	PROPOSED DOUBLE CATCHBASIN
⊗	PROPOSED VALVE & CHAMBER
⋈	PROPOSED VALVE & BOX
	PROPOSED HYDRANT & VALVE
• HP	EXISTING HYDRO POLE
• HP LS	EXISTING HYDRO POLE LIGHT STANDARD
• TLP	EXISTING TRAFFIC LIGHT POLE
• TLP LS	EXISTING TRAFFIC LIGHT POLE/LIGHT STANDARD
• ANCP	EXISTING ANCHOR POLE
○ BMH	EXISTING BELL MANHOLE
□ B.PED	EXISTING BELL PEDESTAL
○ MH	EXISTING MANHOLE
⋈ WV	EXISTING WATER VALVE
⊗ WVC	EXISTING WATER VALVE CHAMBER
HYD	EXISTING HYDRANT
□	EXISTING CATCH BASIN
	100-150mmØ RIVER RUN STONE, 300mm THICK SET ON 100mm THICK 19mmØ CLEARSTONE BED.

The MUNICIPAL INFRASTRUCTURE Group Ltd.
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Vaughan, Ontario, L4K 5X6
Tel. 905-738-5700 Fax 905-738-0065

NOTICE TO CONTRACTOR

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ROGERS CABLE COMMUNICATIONS
BELL CANADA
ENBRIDGE GAS DISTRIBUTION
ONTARIO MINISTRY OF TRANSPORTATION
ONTARIO CLEAN WATER AGENCY
HYDRO ONE NETWORKS
HYDRO ONE BRAMPTON

5m 0 5 10 15m HORIZONTAL SCALE

LICENSED PROFESSIONAL ENGINEER
DESIGN BY
7/28/2010
L. N. RUSSELL
100032788
PROVINCE OF ONTARIO

DEPARTMENTAL APPROVAL

APPROVED BY

MISSISSAUGA Transportation and Works

ELM DRIVE WEST BOULEVARD SITE GRADING PLAN

SCALE	1:250	AREA		PROJECT No.	10121
C.A.D.D. BY:	CAD	CHECKED BY:	C.E.	PLAN N	C48331
DATE	July 28 2010	SHEET	3 OF 5		

ELM DRIVE, CITY OF MISSISSAUGA

LOW IMPACT DEVELOPMENT INFRASTRUCTURE PERFORMANCE AND RISK MANAGEMENT ASSESSMENT

Appendix C
Data Management and Analytical Methodology

1 DATA MANAGEMENT AND ANALYTICAL METHODOLOGY

CVC manages stormwater data produced from the ongoing monitoring of water level, flow and water quality at the Elm Drive LID treatment train. 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 Elm Drive 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 LID 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 Elm Drive Project (herein referred to as the “site” or “ED-1”) monitoring data set provided by CVC. For ED-1, hydrologic data dates from July 2011 and water quality data dates from July 2012.

Reference data included the following data sources:

- 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 Elm Drive Retrofit site was evaluated using event-based analysis, with the event defined as previously indicated in **Table 1-1.** ED-1 was evaluated for both water quantity and water quality performance. This site receives inflow as sheet flow and interflow from the permeable pavement laybys and sidewalk in addition to road runoff, making it difficult to measure inflow directly. Because of this, the Simple Method[1] was selected 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 calculating 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 Elm Drive was derived using orthographic imagery, as-built surveys and site visits. This process allows the catchment area to be divided into impervious, pervious and BMP surfaces, which are used in the equation below to determine the runoff coefficient. Precipitation data is obtained from the rain gauge CVC maintains on the roof of the Adult Education Centre at Elm Drive. This data is used with the drainage area to determine event inflow runoff volume. Table 1-2 presents the drainage area and use of the Simple Method at Elm Drive.

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.

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 Elm Drive

Land Use	**Area (m^2)**
Road	1913
Roof (directed to impervious surfaces)	204
Sidewalk	263
Driveway	198
Total impervious area	**2,578**
Roof (directed to pervious surfaces)	363
Grass	2,839
Total pervious area	**3,203**
Total drainage area to the BMP (impervious area + pervious area)	**5,781**
BMP Area	
Bioretention cells	145
Permeable pavement (sidewalk and laybys)	530
Total BMP area	**675**
Ia= impervious fraction (total impervious area/total drainage area to the BMP)	0.446
Rv= 0.05 + 0.9 * Ia	0.451
Total drainage area to the BMP * Rv + total BMP area: Multiply this number by event precipitation (mm) to get event inflow volume (L)	**3,284**

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.

SWMM Model

A hydrologic model was developed for Elm Drive and used to estimate inflow for the July 8, 2013 event. The model was developed using US EPA SWMM 5, a widely used and publicly available model. The

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

model setup divided the Elm Drive site into six sub-catchments, which included the west residential area, the west road area, the west Bioretention area, the east residential area, the east road area and the east Bioretention area (**Figure 1-1**). The outflow from the two residential areas was routed to their respective road areas, and then into the treatment train of permeable pavers followed by bioretention systems. The outflow from the west bioretention area was routed to the east Bioretention area. **Figure 1-1** illustrates the model setup and identifies the delineation of each of the six sub-catchments. The modeled outflow from the east bioretention was compared to the monitoring data for calibration purposes.

The SWMM LID control editor tool was used, which modeled the permeable pavement and the bioretention systems as components within the road sub-catchments and bioretention sub-catchments, respectively.

The model was run utilizing available precipitation data from January 1, 2013 to July 12, 2013 at a 10-minute time step. The calibration process involved comparing the modeled outflow volume (both from surface runoff and underdrain outflow) from the east Bioretention area to the monitored outflow volume at this location for four storms. The four storms were calibrated to within 31% of volume. The model calibration can be further improved through the calibration with a greater number of storms, of which there is a high certainty of data quality.

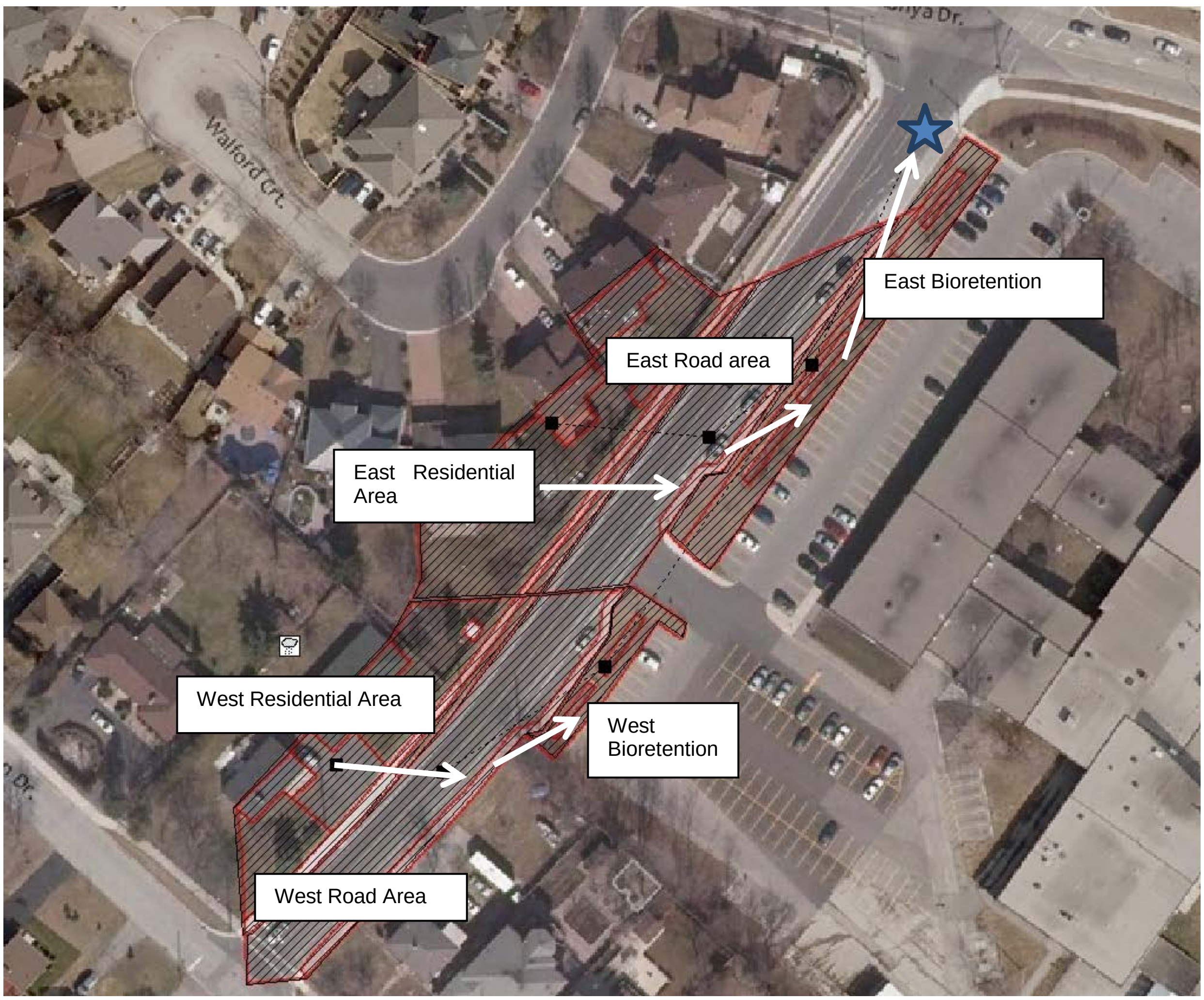

Figure 1-1: View of the SWMM model setup including the delineation outline for each of the six subcatchments. The white arrows indicate the flow direction. Monitoring data was compared to modeled outflow data in the location identified by the blue star.

Water Quality

Both contaminant loadings and discharge concentrations have been evaluated for Elm Drive. 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. An estimated total influent load was calculated as a product of the estimated influent volume and the NSQD Residential median EMC for evaluation purposes. For the July 8, 2013 storm, the 75th-percentile EMC values were used to estimate influent loads due to the magnitude and intensity of the storm being outside average storms in the GTA. Effluent EMCs 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]

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.

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 1-2** is a key for the box plots provided in **Appendix C**.

While box plots summarize the general spread of the data, probability plots illustrate the full empirical distribution of the data. A review of the 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.

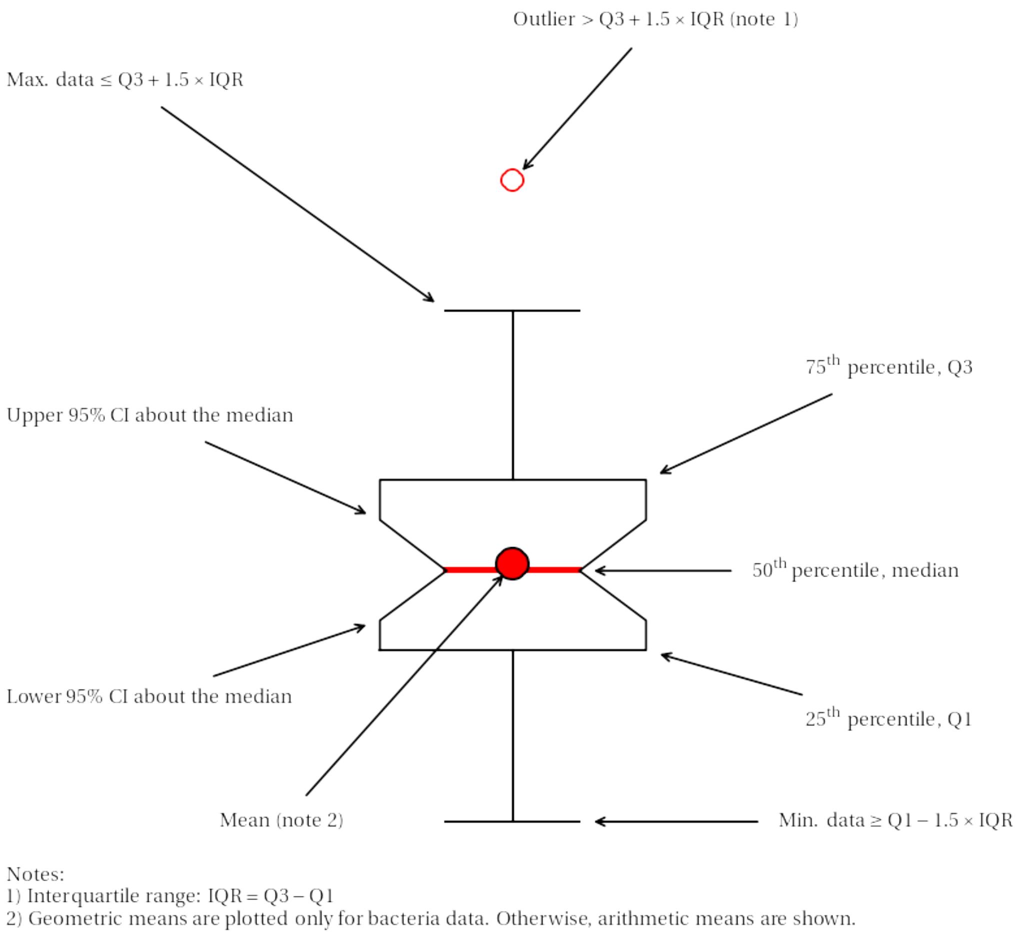

Figure 1-2: Explanation of Box and Whisker Diagram

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 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; green infrastructure.
- *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 Elm Drive 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.

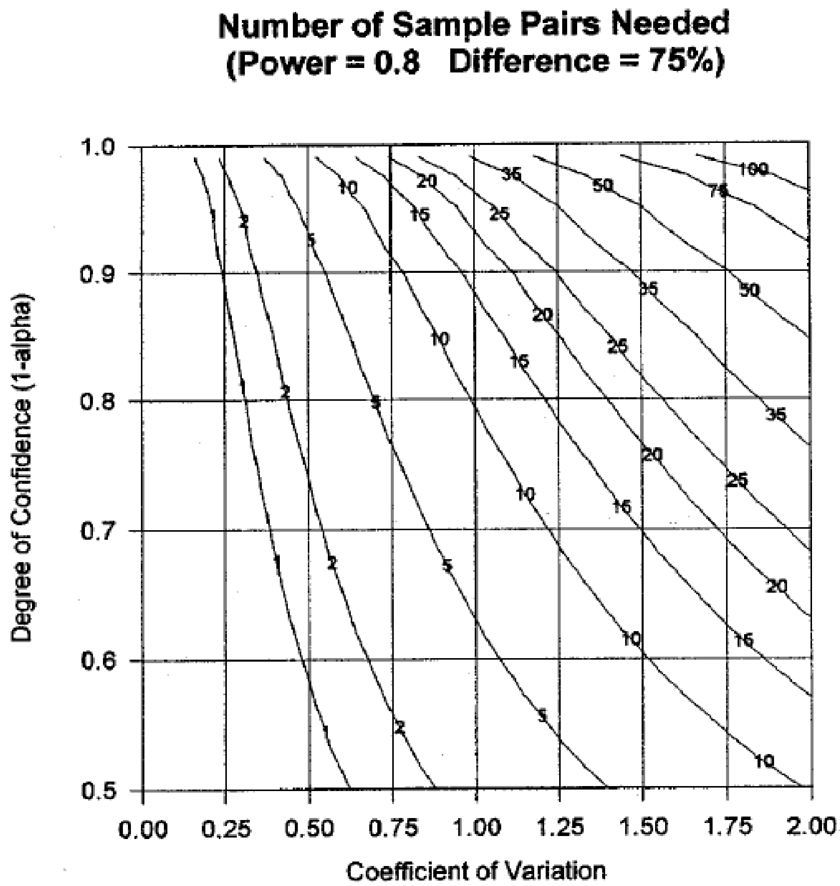

Figure 1-3: Statistical Hypothesis testing paired samples required to detect 75% difference in population means for power of 80% (Pitt and Parmer 1985)

Therefore, eventually it may be possible for CVC to conduct hypothesis testing if inflow EMCs can be estimated 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 is evaluating methods for estimating inflow loads 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 MOECC 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.

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Appendix D

Data Analysis Summaries

1 RAINFALL EVENTS ANALYSIS

Table D-1: Summary of Rainfall Events

Starting Date and Time	Event Duration (hrs)	Precipitation Depth (mm)
2011-07-28 8:30:00	2.0	5.0
2011-07-29 2:00:00	10.3	2.2
2011-08-03 3:20:00	2.0	12.8
2011-08-07 4:10:00	19.8	26.6
2011-08-09 6:20:00	8.2	34.6
2011-08-09 22:50:00	0.8	5.8
2011-08-21 13:50:00	2.8	6.0
2011-08-24 20:20:00	2.2	11.2
2011-09-01 1:10:00	1.3	5.0
2011-09-03 9:20:00	5.5	4.4
2011-09-04 19:00:00	0.8	4.0
2011-09-14 19:30:00	4.7	2.2
2011-09-19 11:50:00	14.5	13.0
2011-09-21 14:00:00	5.2	13.0
2011-09-23 10:30:00	8.5	25.0
2011-09-28 2:40:00	2.2	2.6
2011-09-29 6:40:00	9.5	4.0
2011-09-30 0:10:00	2.2	16.4
2011-09-30 17:30:00	2.0	6.4
2011-10-02 11:00:00	2.5	3.0
2011-10-03 20:10:00	12.5	2.8
2011-10-12 12:10:00	15.8	32.8
2011-10-13 22:40:00	10.0	2.4
2011-10-18 23:30:00	33.0	48.4
2011-10-25 14:10:00	33.8	21.0
2011-11-09 15:40:00	6.8	4.6
2011-11-14 2:10:00	2.0	2.2
2011-11-14 15:50:00	2.0	6.6
2011-11-22 19:00:00	10.2	19.8
2011-11-27 9:10:00	18.8	4.8
2011-11-28 22:30:00	26.3	46.4
2011-12-03 9:20:00	12.8	5.0
2011-12-05 4:30:00	28.3	15.6
2011-12-14 15:00:00	24.3	11.2
2011-12-22 21:10:00	4.3	2.4
2011-12-27 12:00:00	14.0	8.4
2011-12-30 18:00:00	9.2	8.4
2012-01-01 11:00:00	4.8	3.2
2012-01-11 23:50:00	16.8	9.0
2012-01-16 22:00:00	19.0	5.4
2012-01-22 23:50:00	16.3	8.2
2012-01-26 21:00:00	15.8	9.8

Starting Date and Time	Event Duration (hrs)	Precipitation Depth (mm)
2012-01-31 9:10:00	1.5	3.8
2012-02-09 10:00:00	8.2	3.2
2012-02-18 9:20:00	1.8	4.6
2012-02-23 23:50:00	17.3	10.2
2012-02-29 23:50:00	9.8	6.6
2012-03-02 19:40:00	4.3	4.2
2012-03-12 23:50:00	3.2	4.0
2012-04-01 7:40:00	5.0	3.2
2012-04-15 8:00:00	2.5	3.0
2012-04-20 22:20:00	8.3	10.8
2012-04-23 11:10:00	15.8	12.2
2012-04-30 13:50:00	10.2	8.8
2012-05-03 19:40:00	5.3	16.2
2012-05-08 22:00:00	7.7	9.4
2012-05-10 12:20:00	3.5	14.0
2012-05-15 8:40:00	0.3	3.2
2012-06-01 10:50:00	37.2	40.8
2012-06-03 16:20:00	0.7	5.0
2012-06-07 15:40:00	1.8	7.8
2012-06-12 18:20:00	9.5	9.2
2012-06-21 13:00:00	7.7	9.6
2012-07-15 14:30:00	2.5	23.0
2012-07-23 19:50:00	0.5	9.2
2012-07-25 19:10:00	18.2	12.6
2012-07-31 11:50:00	10.7	35.0
2012-08-09 9:00:00	38.7	45.0
2012-08-11 5:30:00	11.3	11.0
2012-08-14 3:30:00	11.5	6.6
2012-08-27 8:50:00	5.3	6.0
2012-09-04 9:10:00	12.2	25.2
2012-09-08 0:10:00	17.7	40.6
2012-09-14 10:40:00	4.2	10.2
2012-09-18 3:50:00	10.5	16.2
2012-09-21 23:40:00	9.0	14.0
2012-10-05 21:40:00	4.8	6.6
2012-10-13 16:50:00	14.3	18.0
2012-10-17 7:30:00	3.2	2.0
2012-10-18 11:10:00	9.3	8.8
2012-10-19 22:30:00	4.7	4.6
2012-10-23 2:00:00	20.8	25.6
2012-10-27 5:40:00	12.2	17.6
2012-10-28 9:10:00	43.2	28.4
2012-10-30 10:40:00	39.7	16.2
2012-11-02 23:40:00	9.3	3.6
2012-11-12 14:50:00	7.0	6.0
2012-12-02 3:40:00	7.7	12.6

Starting Date and Time	Event Duration (hrs)	Precipitation Depth (mm)
2012-12-04 11:40:00	4.5	3.4
2012-12-07 19:10:00	16.3	4.0
2012-12-09 17:50:00	13.0	8.6
2012-12-16 8:50:00	5.3	3.8
2012-12-20 17:20:00	7.3	10.2
2012-12-26 20:40:00	6.0	6.2
2012-12-27 14:50:00	1.5	2.8
2012-12-30 12:20:00	3.7	3.6
2013-01-11 4:00:00	13.5	4.6
2013-01-13 3:10:00	9.5	29.4
2013-01-13 21:00:00	4.8	3.4
2013-01-28 3:40:00	16.2	9.4
2013-01-29 10:10:00	13.2	16.0
2013-01-30 9:00:00	0.8	2.2
2013-02-08 4:40:00	6.5	17.4
2013-02-09 11:40:00	4.2	6.0
2013-02-11 2:40:00	9.7	4.6
2013-02-14 18:20:00	4.8	2.0
2013-02-16 18:00:00	1.8	3.0
2013-02-17 12:30:00	2.7	2.2
2013-02-18 11:10:00	4.0	2.4
2013-02-19 5:20:00	4.3	9.8
2013-02-26 20:10:00	39.7	57.6
2013-03-10 14:20:00	59.2	10.2
2013-03-18 20:00:00	3.8	3.6
2013-04-08 15:20:00	5.8	10.8
2013-04-09 15:10:00	26.0	30.0
2013-04-11 6:00:00	61.0	31.8
2013-04-17 22:20:00	6.5	4.4
2013-04-19 7:50:00	5.5	2.0
2013-04-24 10:30:00	6.3	13.8
2013-04-28 17:20:00	15.0	11.2
2013-05-10 8:40:00	19.8	24.0
2013-05-15 3:20:00	3.2	2.2
2013-05-20 21:30:00	2.2	10.6
2013-05-22 14:00:00	3.0	3.4
2013-05-23 19:10:00	6.2	3.6
2013-05-28 5:50:00	3.5	3.4
2013-05-28 16:10:00	20.7	25.0
2013-05-31 17:10:00	5.7	2.8
2013-06-01 14:00:00	4.7	2.2
2013-06-02 1:00:00	10.3	8.0
2013-06-06 13:20:00	17.2	8.0
2013-06-10 6:20:00	29.7	36.0
2013-06-13 7:20:00	16.5	9.4
2013-06-16 5:00:00	11.2	14.8

Starting Date and Time	Event Duration (hrs)	Precipitation Depth (mm)
2013-06-22 11:50:00	2.0	2.2
2013-06-23 17:10:00	0.2	4.2
2013-06-25 6:10:00	3.2	6.2
2013-06-28 3:40:00	13.0	15.4
2013-07-05 6:10:00	21.3	60.2
2013-07-07 0:30:00	5.2	5.2
2013-07-07 15:30:00	8.8	9.6
2013-07-08 16:30:00	20.2	105.0
2013-07-19 17:00:00	9.2	6.6
2013-07-27 13:00:00	8.0	19.0
2013-07-31 15:50:00	22.3	31.6
2013-08-02 16:20:00	4.2	10.6
2013-08-26 5:50:00	7.3	15.6
2013-08-27 17:30:00	12.7	25.2
2013-09-07 7:50:00	7.5	20.4
2013-09-11 15:30:00	8.2	9.6
2013-09-20 22:10:00	28.0	42.0
2013-09-29 22:00:00	13.5	2.6
2013-10-04 0:30:00	7.8	6.2
2013-10-07 1:40:00	6.5	8.2
2013-10-13 7:30:00	9.3	8.4
2013-10-16 0:40:00	4.8	5.8
2013-10-17 16:20:00	4.8	8.2
2013-10-19 11:40:00	6.7	7.6
2013-10-21 18:20:00	8.3	8.2
2013-10-26 5:40:00	6.3	7.4
2013-10-31 3:30:00	6.7	15.2
2013-10-31 17:20:00	11.5	5.2
2013-11-06 16:30:00	8.2	5.8
2013-11-17 2:50:00	2.7	3.6
2013-11-17 20:20:00	6.8	10.4
2013-11-21 22:40:00	6.5	5.6
2013-11-26 21:00:00	5.3	2.6
2013-12-14 9:50:00	6.2	3.8
2013-12-16 13:30:00	0.7	2.8
2013-12-19 23:40:00	67.3	48.6
2013-12-26 2:40:00	12.2	2.4
2014-01-05 1:50:00	26.3	22.0
2014-01-10 1:20:00	7.5	7.0
2014-01-11 0:30:00	18.2	25.8
2014-01-17 0:10:00	3.7	2.0
2014-01-26 5:00:00	2.8	7.8
2014-01-31 5:30:00	3.5	10.0
2014-02-01 10:30:00	17.8	18.8
2014-02-06 5:10:00	9.5	3.4
2014-02-18 1:20:00	3.7	5.2

Starting Date and Time	Event Duration (hrs)	Precipitation Depth (mm)
2014-02-20 16:10:00	17.2	22.8
2014-03-02 13:30:00	0.3	3.6
2014-03-11 14:10:00	4.0	
2014-03-12 6:40:00	9.7	12.6
2014-03-19 16:10:00	5.2	2.8
2014-03-27 17:40:00	16.0	2.0
2014-04-04 11:50:00	10.0	6.6
2014-04-07 17:50:00	25.2	14.2
2014-04-12 23:10:00	3.0	8.2
2014-04-14 12:40:00	2.7	5.4
2014-04-15 0:00:00	20.0	11.4
2014-04-22 4:00:00	5.7	2.2
2014-04-25 15:20:00	4.8	5.6
2014-04-29 7:10:00	53.0	48.8
2014-05-13 3:30:00	3.0	14.0
2014-05-13 19:00:00	3.3	6.6
2014-05-14 17:20:00	11.3	10.2
2014-05-15 10:50:00	29.5	16.8
2014-05-19 17:20:00	0.3	2.0
2014-05-20 13:10:00	7.0	2.0
2014-05-27 15:50:00	1.8	6.2
2014-06-02 22:50:00	6.8	7.4
2014-06-08 14:30:00	3.7	2.6
2014-06-11 5:40:00	3.2	2.4
2014-06-11 21:20:00	3.7	15.2
2014-06-17 18:00:00	3.3	7.4
2014-06-23 17:00:00	0.7	2.8
2014-06-24 15:50:00	4.2	4.6
2014-06-25 17:40:00	6.5	4.4
2014-07-01 9:00:00	0.3	6.6
2014-07-07 2:30:00	4.5	11.6
2014-07-08 11:40:00	3.0	8.8
2014-07-13 5:20:00	4.7	9.6
2014-07-15 1:20:00	9.8	4.6
2014-07-16 14:50:00	0.3	2.8
2014-07-19 13:40:00	8.5	8.2
2014-07-20 14:10:00	0.8	2.0
2014-07-27 19:00:00	21.3	38.8
2014-08-04 14:50:00	3.7	10.8
2014-08-11 22:40:00	7.2	20.4
2014-08-20 19:40:00	0.7	6.6
2014-09-01 21:00:00	1.2	2.6
2014-09-02 11:30:00	4.3	15.8
2014-09-05 19:10:00	15.7	33.8
2014-09-10 16:00:00	18.5	27.0
2014-09-13 8:10:00	6.0	2.0

Starting Date and Time	Event Duration (hrs)	Precipitation Depth (mm)
2014-09-15 10:20:00	13.3	4.6
2014-09-21 5:50:00	13.8	24.6
2014-10-03 13:30:00	16.2	13.8
2014-10-07 16:00:00	6.0	9.6
2014-10-15 0:10:00	6.5	2.8
2014-10-16 16:50:00	1.7	11.4
2014-10-20 6:30:00	13.3	7.0
2014-10-21 10:20:00	9.2	2.6
2014-10-31 3:40:00	23.5	13.4
2014-11-04 16:00:00	4.8	3.6
2014-11-06 17:40:00	6.8	3.0
2014-11-16 21:40:00	16.5	6.0
2014-11-19 16:20:00	1.7	2.0
2014-11-24 0:10:00	13.5	21.0
2014-12-11 3:30:00	21.2	12.8
2014-12-16 1:00:00	36.2	6.8
2014-12-23 23:50:00	26.3	9.6
2015-01-03 12:40:00	31.2	18.8
2015-01-29 13:00:00	7.0	5.6
2015-02-07 10:40:00	10.2	2.0
2015-02-21 9:10:00	9.0	6.0
2015-03-04 10:00:00	2.2	5.4
2015-03-11 15:10:00	2.0	
2015-03-16 19:00:00	13.7	2.0
2015-03-21 1:50:00	5.3	2.4
2015-03-25 11:20:00	4.5	4.0
2015-04-02 18:30:00	0.8	4.2
2015-04-03 17:50:00	1.8	4.0
2015-04-05 9:20:00	2.3	3.0
2015-04-08 7:30:00	60.7	35.8
2015-04-13 17:00:00	1.7	6.8
2015-04-19 22:30:00	27.5	32.0
2015-05-10 11:40:00	7.8	13.6
2015-05-11 20:00:00	1.8	8.0
2015-05-30 12:40:00	36.0	55.4
2015-06-05 14:10:00	1.2	8.6
2015-06-07 21:00:00	23.2	33.4
2015-06-10 11:10:00	6.5	6.4
2015-06-12 4:10:00	2.5	3.2
2015-06-12 13:30:00	4.7	4.2
2015-06-14 7:50:00	8.7	6.6
2015-06-16 2:40:00	6.8	13.0
2015-06-22 18:10:00	9.2	14.8
2015-06-27 10:50:00	40.2	62.0
2015-07-07 13:10:00	8.0	8.4
2015-07-14 8:10:00	0.5	2.6

Starting Date and Time	Event Duration (hrs)	Precipitation Depth (mm)
2015-07-17 10:30:00	5.3	5.2
2015-07-19 15:10:00	4.0	22.4
2015-08-02 16:50:00	10.8	19.8
2015-08-04 17:30:00	0.3	2.8
2015-08-10 12:10:00	9.8	31.0
2015-08-14 5:30:00	4.3	2.0
2015-08-19 22:10:00	0.7	5.4
2015-08-20 9:10:00	2.8	10.8
2015-09-09 7:30:00	1.5	6.4
2015-09-11 18:50:00	13.7	17.8
2015-09-12 14:30:00	25.8	13.2
2015-09-19 14:10:00	0.8	9.8
2015-09-29 12:30:00	9.7	26.6

2 HYDROLOGIC ANALYSIS

Table D-2: Hydrologic Summary of Rainfall Events

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)	(%)
2011-07-28 8:30:00	3.1	16421	5.5	0		100.0	16421	100.0
2011-07-29 2:00:00	0.6	7225	3.3	0		100.0	7225	100.0
2011-08-03 3:20:00	2.7	42038	10.9	0		100.0	42038	100.0
2011-08-07 4:10:00	2.7	87361	35.0	45700	3.6	89.6	41661	47.7
2011-08-09 6:20:00	1.3	113635	18.6	6949	1.7	90.6	106686	93.9
2011-08-09 22:50:00	0.3	19049	13.1	0		100.0	19049	100.0
2011-08-21 13:50:00	0.4	19706	26.3	0		100.0	19706	100.0
2011-08-24 20:20:00	0.4	36784	25.2	0		100.0	36784	100.0
2011-09-01 1:10:00	6.7	16421	4.4	0		100.0	16421	100.0
2011-09-03 9:20:00	1.8	14451	13.1	0		100.0	14451	100.0
2011-09-04 19:00:00	0.3	13137	9.9	0		100.0	13137	100.0
2011-09-14 19:30:00	6.3	7225	2.2	0		100.0	7225	100.0
2011-09-19 11:50:00	4.0	42695	9.9	0		100.0	42695	100.0
2011-09-21 14:00:00	1.5	42695	15.3	0		100.0	42695	100.0
2011-09-23 10:30:00	0.9	82106	30.7	0		100.0	82106	100.0
2011-09-28 2:40:00	0.5	8539	3.3	0		100.0	8539	100.0
2011-09-29 6:40:00	0.4	13137	4.4	0		100.0	13137	100.0
2011-09-30 0:10:00	0.3	53862	37.2	0		100.0	53862	100.0
2011-09-30 17:30:00	0.6	21019	7.7	0		100.0	21019	100.0
2011-10-02 11:00:00	1.2	9853	4.4	0		100.0	9853	100.0
2011-10-03 20:10:00	0.6	9196	2.2	0		100.0	9196	100.0
2011-10-12 12:10:00	8.1	107723	7.7	32078	4.2	45.1	75645	70.2
2011-10-13 22:40:00	0.8	7882	5.5	0		100.0	7882	100.0
2011-10-18 23:30:00	1.5	158958	12.0	75102	5.5	54.3	83856	52.8
2011-10-25 14:10:00	1.1	68969	4.4	0		100.0	68969	100.0
2011-11-09 15:40:00	1.2	15108	3.3	0		100.0	15108	100.0
2011-11-14 2:10:00	4.2	7225	5.5	0		100.0	7225	100.0
2011-11-14 15:50:00	0.5	21676	5.5	0		100.0	21676	100.0
2011-11-22 19:00:00	8.0	65028	4.4	0		100.0	65028	100.0
2011-11-27 9:10:00	1.8	15764	2.2	0		100.0	15764	100.0
2011-11-28 22:30:00	0.4	152389	7.7	20909	2.6	66.0	131480	86.3
2011-12-03 9:20:00	1.0	16421	2.2	0		100.0	16421	100.0
2011-12-05 4:30:00	1.3	51234	2.2	0		100.0	51234	100.0
2011-12-14 15:00:00	8.3	36784	7.7	0		100.0	36784	100.0
2011-12-22 21:10:00	1.2	7882	2.2	0		100.0	7882	100.0
2011-12-27 12:00:00	4.4	27588	2.2	0		100.0	27588	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)	(%)
2011-12-30 18:00:00	2.7	27588	6.6	0		100.0	27588	100.0
2012-01-01 11:00:00	0.5	10510	4.4	0		100.0	10510	100.0
2012-01-11 23:50:00	10.3	29558	3.3	0		100.0	29558	100.0
2012-01-16 22:00:00	0.9	17735	3.3	0		100.0	17735	100.0
2012-01-22 23:50:00	1.0	26931	6.6	0		100.0	26931	100.0
2012-01-26 21:00:00	0.4	32186	3.3	0		100.0	32186	100.0
2012-01-31 9:10:00	0.4	12480	4.4	0		100.0	12480	100.0
2012-02-09 10:00:00	0.4	10510	1.1	0		100.0	10510	100.0
2012-02-18 9:20:00	0.4	15108	3.3	0		100.0	15108	100.0
2012-02-23 23:50:00	2.0	33499	3.3	0		100.0	33499	100.0
2012-02-29 23:50:00	5.3	21676	3.3	0		100.0	21676	100.0
2012-03-02 19:40:00	0.8	13794	6.6	0		100.0	13794	100.0
2012-03-12 23:50:00	0.4	13137	7.7	0		100.0	13137	100.0
2012-04-01 7:40:00	0.3	10510	3.3	0		100.0	10510	100.0
2012-04-15 8:00:00	0.3	9853	3.3	0		100.0	9853	100.0
2012-04-20 22:20:00	0.9	35470	4.4	0		100.0	35470	100.0
2012-04-23 11:10:00	0.5	40068	3.3	0		100.0	40068	100.0
2012-04-30 13:50:00	0.6	28901	3.3	0		100.0	28901	100.0
2012-05-03 19:40:00	0.6	53205	27.4	0		100.0	53205	100.0
2012-05-08 22:00:00	0.9	30872	4.4	0		100.0	30872	100.0
2012-05-10 12:20:00	0.5	45980	18.6	0		100.0	45980	100.0
2012-05-15 8:40:00	0.4	10510	16.4	0		100.0	10510	100.0
2012-06-01 10:50:00	3.1	133997	14.2	41105	2.4	83.3	92893	69.3
2012-06-03 16:20:00	0.7	16421	12.0	0		100.0	16421	100.0
2012-06-07 15:40:00	0.7	25617	14.2	0		100.0	25617	100.0
2012-06-12 18:20:00	0.8	30215	8.8	0		100.0	30215	100.0
2012-06-21 13:00:00	2.4	31529	15.3	0		100.0	31529	100.0
2012-07-15 14:30:00	8.2	75538	49.3	0		100.0	75538	100.0
2012-07-23 19:50:00	8.1	30215	33.9	0		100.0	30215	100.0
2012-07-25 19:10:00	1.5	41382	16.4	0		100.0	41382	100.0
2012-07-31 11:50:00	4.9	114949	58.0	51707	11.0	81.1	63241	55.0
2012-08-09 9:00:00	3.8	147791	50.4	87748	7.3	85.5	60043	40.6
2012-08-11 5:30:00	0.2	36127	21.9	16043	2.6	88.1	20083	55.6
2012-08-14 3:30:00	1.7	21676	4.4	0		100.0	21676	100.0
2012-08-27 8:50:00	10.0	19706	6.6	0		100.0	19706	100.0
2012-09-04 9:10:00	7.8	82763	46.0	2265	0.4	99.2	80498	97.3
2012-09-08 0:10:00	2.6	133341	27.4	73397	9.3	66.0	59943	45.0
2012-09-14 10:40:00	5.7	33499	8.8	0		100.0	33499	100.0
2012-09-18 3:50:00	3.5	53205	5.5	0		100.0	53205	100.0
2012-09-21 23:40:00	1.4	45980	7.7	0		100.0	45980	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)	(%)
2012-10-05 21:40:00	13.5	21676	3.3	0		100.0	21676	100.0
2012-10-13 16:50:00	1.2	59117	8.8	0		100.0	59117	100.0
2012-10-17 7:30:00	1.7	6569	3.3	0		100.0	6569	100.0
2012-10-18 11:10:00	1.0	28901	12.0	0		100.0	28901	100.0
2012-10-19 22:30:00	0.4	15108	5.5	0		100.0	15108	100.0
2012-10-23 2:00:00	2.0	84077	9.9	24823	1.2	88.0	59254	70.5
2012-10-27 5:40:00	0.3	57803	3.3	268	0.1	97.2	57535	99.5
2012-10-28 9:10:00	0.6	93273	6.6	6465	0.6	90.6	86808	93.1
2012-10-30 10:40:00	0.3	53205	10.9	39635	6.7	38.9	13570	25.5
2012-11-02 23:40:00	0.4	11823	3.3	0		100.0	11823	100.0
2012-11-12 14:50:00	1.6	19706	2.2	0		100.0	19706	100.0
2012-12-02 3:40:00	0.6	41382	5.5	0		100.0	41382	100.0
2012-12-04 11:40:00	2.0	11166	3.3	0		100.0	11166	100.0
2012-12-07 19:10:00	3.1	13137	3.3	0		100.0	13137	100.0
2012-12-09 17:50:00	1.3	28245	4.4	0		100.0	28245	100.0
2012-12-16 8:50:00	4.8	12480	4.4	0		100.0	12480	100.0
2012-12-20 17:20:00	4.1	33499	3.3	0		100.0	33499	100.0
2012-12-26 20:40:00	1.4	20362	8.8	0		100.0	20362	100.0
2012-12-27 14:50:00	0.5	9196	5.5	0		100.0	9196	100.0
2012-12-30 12:20:00	2.8	11823	6.6	0		100.0	11823	100.0
2013-01-11 4:00:00	4.7	15108	3.3	0		100.0	15108	100.0
2013-01-13 3:10:00	1.4	96557	10.9	67379	5.5	49.7	29178	30.2
2013-01-13 21:00:00	0.3	11166	3.3	0		100.0	11166	100.0
2013-01-28 3:40:00	2.4	30872	3.3	0		100.0	30872	100.0
2013-01-29 10:10:00	0.6	52548	6.6	7738	1.1	82.9	44810	85.3
2013-01-30 9:00:00	0.4	7225	3.3	0		100.0	7225	100.0
2013-02-08 4:40:00	0.4	57146	9.9	0		100.0	57146	100.0
2013-02-09 11:40:00	1.0	19706	5.5	0		100.0	19706	100.0
2013-02-11 2:40:00	1.5	15108	3.3	0		100.0	15108	100.0
2013-02-14 18:20:00	3.3	6569	2.2	0		100.0	6569	100.0
2013-02-16 18:00:00	1.8	9853	5.5	0		100.0	9853	100.0
2013-02-17 12:30:00	0.7	7225	2.2	0		100.0	7225	100.0
2013-02-18 11:10:00	0.8	7882	5.5	0		100.0	7882	100.0
2013-02-19 5:20:00	0.6	32186	4.4	0		100.0	32186	100.0
2013-02-26 20:10:00	2.4	189173	10.9	10	0.0	99.9	189163	100.0
2013-03-10 14:20:00	2.4	33499	2.2	71825	1.2	45.9	-38325	-114.4
2013-03-18 20:00:00	5.4	11823	7.7	0		100.0	11823	100.0
2013-04-08 15:20:00	1.3	35470	12.0	0		100.0	35470	100.0
2013-04-09 15:10:00	0.8	98528	18.6	3187	0.3	98.6	95341	96.8

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)	Estimated Volume Reduction (%)
2013-04-11 6:00:00	0.5	104439	7.7	41338	1.2	83.7	63101	60.4
2013-04-17 22:20:00	1.6	14451	6.6	0		100.0	14451	100.0
2013-04-19 7:50:00	0.3	6569	3.3	0		100.0	6569	100.0
2013-04-24 10:30:00	4.1	45323	6.6	0		100.0	45323	100.0
2013-04-28 17:20:00	3.0	36784	4.4	0		100.0	36784	100.0
2013-05-10 8:40:00	1.0	78822	23.0	9030	1.0	95.6	69792	88.5
2013-05-15 3:20:00	2.5	7225	4.4	0		100.0	7225	100.0
2013-05-20 21:30:00	5.6	34813	27.4	0		100.0	34813	100.0
2013-05-22 14:00:00	1.6	11166	10.9	0		100.0	11166	100.0
2013-05-23 19:10:00	1.1	11823	2.2	0		100.0	11823	100.0
2013-05-28 5:50:00	4.2	11166	3.3	0		100.0	11166	100.0
2013-05-28 16:10:00	0.3	82106	27.4	9959	1.2	95.4	72147	87.9
2013-05-31 17:10:00	2.2	9196	5.5	0		100.0	9196	100.0
2013-06-01 14:00:00	0.6	7225	3.3	0		100.0	7225	100.0
2013-06-02 1:00:00	0.3	26274	7.7	0		100.0	26274	100.0
2013-06-06 13:20:00	4.1	26274	4.4	0		100.0	26274	100.0
2013-06-10 6:20:00	3.0	118233	23.0	50941	3.7	84.0	67292	56.9
2013-06-13 7:20:00	1.8	30872	17.5	0		100.0	30872	100.0
2013-06-16 5:00:00	2.2	48607	13.1	5075	0.9	93.3	43532	89.6
2013-06-22 11:50:00	5.8	7225	4.4	0		100.0	7225	100.0
2013-06-23 17:10:00	0.9	13794	23.0	0		100.0	13794	100.0
2013-06-25 6:10:00	0.8	20362	16.4	0		100.0	20362	100.0
2013-06-28 3:40:00	2.8	50577	31.7	1075	0.3	99.1	49502	97.9
2013-07-05 6:10:00	0.6	197712	107.3	86032	10.5	90.2	111680	56.5
2013-07-07 0:30:00	0.9	17078	6.6	0		100.0	17078	100.0
2013-07-07 15:30:00	0.4	31529	19.7	2190	0.2	98.9	29339	93.1
2013-07-08 16:30:00	0.7	344846	221.1	250965	82.8	62.6	93881	27.2
2013-07-19 17:00:00	9.5	21676	8.8	0		100.0	21676	100.0
2013-07-27 13:00:00	7.5	62401	71.2	781	0.4	99.5	61620	98.7
2013-07-31 15:50:00	3.8	103782	9.9	21422	1.4	86.0	82361	79.4
2013-08-02 16:20:00	1.1	34813	9.9	0		100.0	34813	100.0
2013-08-26 5:50:00	0.3	51234	20.8	0		100.0	51234	100.0
2013-08-27 17:30:00	1.2	82763	39.4	20959	3.7	90.7	61805	74.7
2013-09-07 7:50:00	4.9	66999	14.2	850	0.2	98.7	66149	98.7
2013-09-11 15:30:00	4.0	31529	5.5	0		100.0	31529	100.0
2013-09-20 22:10:00	8.4	137939	25.2	51818	2.1	91.5	86120	62.4
2013-09-29 22:00:00	0.6	8539	2.2	0		100.0	8539	100.0
2013-10-04 0:30:00	3.5	20362	5.5	0		100.0	20362	100.0
2013-10-07 1:40:00	0.7	26931	5.5	0		100.0	26931	100.0
2013-10-13 7:30:00	2.7	27588	10.9	0		100.0	27588	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)	(%)
2013-10-16 0:40:00	2.3	19049	4.4	0		100.0	19049	100.0
2013-10-17 16:20:00	1.1	26931	6.6	0		100.0	26931	100.0
2013-10-19 11:40:00	1.6	24960	4.4	0		100.0	24960	100.0
2013-10-21 18:20:00	2.0	26931	3.3	0		100.0	26931	100.0
2013-10-26 5:40:00	0.5	24303	2.2	0		100.0	24303	100.0
2013-10-31 3:30:00	1.1	49921	7.7	0		100.0	49921	100.0
2013-10-31 17:20:00	0.3	17078	4.4	0		100.0	17078	100.0
2013-11-06 16:30:00	4.0	19049	3.3	0		100.0	19049	100.0
2013-11-17 2:50:00	5.5	11823	5.5	0		100.0	11823	100.0
2013-11-17 20:20:00	0.6	34156	13.1	0		100.0	34156	100.0
2013-11-21 22:40:00	3.8	18392	3.3	0		100.0	18392	100.0
2013-11-26 21:00:00	4.1	8539	2.2	0		100.0	8539	100.0
2013-12-14 9:50:00	5.1	12480	4.4	0		100.0	12480	100.0
2013-12-16 13:30:00	1.9	9196	13.1	0		100.0	9196	100.0
2013-12-19 23:40:00	0.3	159615	10.9	37210	1.1	89.8	122405	76.7
2013-12-26 2:40:00	0.4	7882	1.1	0		100.0	7882	100.0
2014-01-05 1:50:00	6.7	72254	6.6	0		100.0	72254	100.0
2014-01-10 1:20:00	0.7	22990	5.5	0		100.0	22990	100.0
2014-01-11 0:30:00	0.7	84734	10.9	0		100.0	84734	100.0
2014-01-17 0:10:00	1.6	6569	2.2	0		100.0	6569	100.0
2014-01-26 5:00:00	0.9	25617	6.6	0		100.0	25617	100.0
2014-01-31 5:30:00	4.1	32843	5.5	0		100.0	32843	100.0
2014-02-01 10:30:00	1.1	61744	3.3	0		100.0	61744	100.0
2014-02-06 5:10:00	0.6	11166	2.2	0		100.0	11166	100.0
2014-02-18 1:20:00	8.4	17078	3.3	0		100.0	17078	100.0
2014-02-20 16:10:00	2.0	74881	10.9	0		100.0	74881	100.0
2014-03-02 13:30:00	8.9	11823	9.9	0		100.0	11823	100.0
2014-03-11 14:10:00	6.2	0		3467	0.4		-3467	
2014-03-12 6:40:00	0.5	41382	3.3	0		100.0	41382	100.0
2014-03-19 16:10:00	4.8	9196	2.2	0		100.0	9196	100.0
2014-03-27 17:40:00	4.2	6569	2.2	0		100.0	6569	100.0
2014-04-04 11:50:00	7.1	21676	5.5	0		100.0	21676	100.0
2014-04-07 17:50:00	2.8	46636	5.5	47317	1.1	80.6	-680	-1.5
2014-04-12 23:10:00	4.2	26931	6.6	0		100.0	26931	100.0
2014-04-14 12:40:00	1.4	17735	3.3	0		100.0	17735	100.0
2014-04-15 0:00:00	0.4	37440	6.6	25264	0.9	85.6	12176	32.5
2014-04-22 4:00:00	3.6	7225	2.2	0		100.0	7225	100.0
2014-04-25 15:20:00	3.2	18392	3.3	0		100.0	18392	100.0
2014-04-29 7:10:00	3.5	160271	15.3	91413	3.2	79.3	68858	43.0
2014-05-13 3:30:00	3.5	45980	29.6	136	0.1	99.8	45844	99.7

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)	(%)
2014-05-13 19:00:00	0.5	21676	23.0	0		100.0	21676	100.0
2014-05-14 17:20:00	0.8	33499	14.2	14588	0.9	93.4	18911	56.5
2014-05-15 10:50:00	0.3	55175	4.4	41996	1.1	74.4	13179	23.9
2014-05-19 17:20:00	1.1	6569	8.8	0		100.0	6569	100.0
2014-05-20 13:10:00	0.8	6569	2.2	0		100.0	6569	100.0
2014-05-27 15:50:00	4.3	20362	17.5	0		100.0	20362	100.0
2014-06-02 22:50:00	6.2	24303	4.4	0		100.0	24303	100.0
2014-06-08 14:30:00	5.4	8539	3.3	0		100.0	8539	100.0
2014-06-11 5:40:00	2.5	7882	3.3	0		100.0	7882	100.0
2014-06-11 21:20:00	0.5	49921	14.2	0		100.0	49921	100.0
2014-06-17 18:00:00	0.3	24303	25.2	0		100.0	24303	100.0
2014-06-23 17:00:00	4.9	9196	8.8	0		100.0	9196	100.0
2014-06-24 15:50:00	0.5	15108	5.5	0		100.0	15108	100.0
2014-06-25 17:40:00	0.9	14451	4.4	0		100.0	14451	100.0
2014-07-01 9:00:00	5.4	21676	30.7	0		100.0	21676	100.0
2014-07-07 2:30:00	3.6	38097	6.6	0		100.0	38097	100.0
2014-07-08 11:40:00	0.9	28901	17.5	0		100.0	28901	100.0
2014-07-13 5:20:00	4.6	31529	15.3	0		100.0	31529	100.0
2014-07-15 1:20:00	1.6	15108	8.8	0		100.0	15108	100.0
2014-07-16 14:50:00	1.2	9196	14.2	0		100.0	9196	100.0
2014-07-19 13:40:00	2.9	26931	4.4	0		100.0	26931	100.0
2014-07-20 14:10:00	0.7	6569	5.5	0		100.0	6569	100.0
2014-07-27 19:00:00	4.6	127429	10.9	54620	2.2	79.7	72809	57.1
2014-08-04 14:50:00	5.0	35470	30.7	0		100.0	35470	100.0
2014-08-11 22:40:00	6.1	66999	12.0	51	0.0	99.8	66948	99.9
2014-08-20 19:40:00	0.5	21676	15.3	0		100.0	21676	100.0
2014-09-01 21:00:00	0.3	8539	3.3	0		100.0	8539	100.0
2014-09-02 11:30:00	0.6	51891	50.4	762	0.3	99.5	51129	98.5
2014-09-05 19:10:00	3.1	111008	31.7	31416	1.6	94.8	79592	71.7
2014-09-10 16:00:00	4.2	88675	23.0	18564	1.2	94.8	70111	79.1
2014-09-13 8:10:00	1.9	6569	3.3	0		100.0	6569	100.0
2014-09-15 10:20:00	1.8	15108	4.4	0		100.0	15108	100.0
2014-09-21 5:50:00	0.3	80793	26.3	20991	2.5	90.4	59802	74.0
2014-10-03 13:30:00	11.7	45323	18.6	0		100.0	45323	100.0
2014-10-07 16:00:00	0.3	31529	4.4	0		100.0	31529	100.0
2014-10-15 0:10:00	5.5	9196	2.2	0		100.0	9196	100.0
2014-10-16 16:50:00	1.4	37440	24.1	0		100.0	37440	100.0
2014-10-20 6:30:00	3.5	22990	7.7	0		100.0	22990	100.0
2014-10-21 10:20:00	0.6	8539	2.2	0		100.0	8539	100.0
2014-10-31 3:40:00	1.9	44009	3.3	0		100.0	44009	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)	(%)
2014-11-04 16:00:00	0.4	11823	2.2	0		100.0	11823	100.0
2014-11-06 17:40:00	1.9	9853	3.3	0		100.0	9853	100.0
2014-11-16 21:40:00	2.5	19706	2.2	0		100.0	19706	100.0
2014-11-19 16:20:00	2.1	6569	5.5	0		100.0	6569	100.0
2014-11-24 0:10:00	0.5	68969	10.9	63436	3.5	68.0	5534	8.0
2014-12-11 3:30:00	8.2	42038	2.2	0		100.0	42038	100.0
2014-12-16 1:00:00	1.9	22333	2.2	0		100.0	22333	100.0
2014-12-23 23:50:00	6.1	31529	4.4	0		100.0	31529	100.0
2015-01-03 12:40:00	2.3	61744	3.3	39161	1.6	52.0	22583	36.6
2015-01-29 13:00:00	11.2	18392	3.3	0		100.0	18392	100.0
2015-02-07 10:40:00	2.7	6569	1.1	0		100.0	6569	100.0
2015-02-21 9:10:00	9.7	19706	2.2	0		100.0	19706	100.0
2015-03-04 10:00:00	8.2	17735	4.4	0		100.0	17735	100.0
2015-03-11 15:10:00	1.7	0		1453	0.4		-1453	
2015-03-16 19:00:00	5.1	6569	1.1	0		100.0	6569	100.0
2015-03-21 1:50:00	3.7	7882	2.2	0		100.0	7882	100.0
2015-03-25 11:20:00	4.2	13137	4.4	0		100.0	13137	100.0
2015-04-02 18:30:00	3.4	13794	7.7	0		100.0	13794	100.0
2015-04-03 17:50:00	0.9	13137	4.4	0		100.0	13137	100.0
2015-04-05 9:20:00	1.6	9853	12.0	0		100.0	9853	100.0
2015-04-08 7:30:00	2.8	117576	14.2	137471	2.0	86.0	-19895	-16.9
2015-04-13 17:00:00	2.9	22333	10.9	0		100.0	22333	100.0
2015-04-19 22:30:00	2.8	105096	6.6	79714	1.7	73.9	25382	24.2
2015-05-10 11:40:00	0.4	44666	35.0	130	0.1	99.7	44536	99.7
2015-05-11 20:00:00	1.0	26274	25.2	0		100.0	26274	100.0
2015-05-30 12:40:00	18.6	181947	24.1	60994	2.5	89.5	120954	66.5
2015-06-05 14:10:00	4.6	28245	21.9	0		100.0	28245	100.0
2015-06-07 21:00:00	1.8	109694	37.2	62321	3.7	90.1	47373	43.2
2015-06-10 11:10:00	1.3	21019	17.5	0		100.0	21019	100.0
2015-06-12 4:10:00	1.4	10510	4.4	0		100.0	10510	100.0
2015-06-12 13:30:00	0.3	13794	14.2	0		100.0	13794	100.0
2015-06-14 7:50:00	1.6	21676	5.5	0		100.0	21676	100.0
2015-06-16 2:40:00	1.4	42695	17.5	1129	0.2	98.7	41567	97.4
2015-06-22 18:10:00	6.4	48607	28.5	0		100.0	48607	100.0
2015-06-27 10:50:00	4.3	203624	12.0	77864	1.4	88.0	125759	61.8
2015-07-07 13:10:00	6.0	27588	14.2	0		100.0	27588	100.0
2015-07-14 8:10:00	6.5	8539	10.9	0		100.0	8539	100.0
2015-07-17 10:30:00	2.6	17078	4.4	0		100.0	17078	100.0
2015-07-19 15:10:00	0.9	73567	101.8	12757	3.0	97.0	60810	82.7
2015-08-02 16:50:00	1.8	65028	27.4	0		100.0	65028	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)	(%)
2015-08-04 17:30:00	1.1	9196	14.2	0		100.0	9196	100.0
2015-08-10 12:10:00	5.8	101812	32.8	20987	3.0	90.9	80824	79.4
2015-08-14 5:30:00	3.3	6569	1.1	0		100.0	6569	100.0
2015-08-19 22:10:00	4.6	17735	23.0	0		100.0	17735	100.0
2015-08-20 9:10:00	0.4	35470	28.5	0		100.0	35470	100.0
2015-09-09 7:30:00	0.7	21019	18.6	0		100.0	21019	100.0
2015-09-11 18:50:00	2.4	58460	5.5	0		100.0	58460	100.0
2015-09-12 14:30:00	0.3	43352	5.5	0		100.0	43352	100.0
2015-09-19 14:10:00	5.9	32186	21.9	0		100.0	32186	100.0
2015-09-29 12:30:00	1.1	87361	20.8	16585	1.6	92.1	70776	81.0

3 WATER QUALITY PERFORMANCE

Table D-3: EMC Summary for All Events

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)
2012-07-31 11:50:00	35	110	0.13	0.052	1.5	1.2	0.16	8.6	1350	6.13	2.2	43.3
2012-08-09 9:00:00	45	11	0.036	0.035	1.4	0.57	0.09	5.3	223	1.9	0.9	14
2012-08-11 5:30:00	11	21	0.056	0.037	1	0.3	0.05	4.7	286	1.24	0.7	11.3
2012-09-04 9:10:00	25.2	13	0.065	0.035	1.7	0.62	0.1	3.4	211	0.94	0.5	9
2012-10-23 2:00:00	25.6	3	0.034	0.038	1.4	0.65	0.09	5.1	62	0.3	0.2	4
2012-10-28 9:10:00	28.4	6	0.009	0.023	1.1	0.15	0.09	5.1	118	0.5	0.5	6
2013-05-10 8:40:00	24	32	0.065	0.02	1.3	0.67	0.1	14.7	391	1.82	1	17.1
2013-05-28 16:10:00	25	340	0.066	0.032	1.5	0.45	0.21	8.8	308	1.57	1.3	17
2013-06-16 5:00:00	14.8	47	0.16	0.063	1.2	0.44	0.2	13.3	307	1.5	0.7	14
2013-07-05 6:10:00	60.2	31	0.08	0.046	0.97	0.55	0.2	6.9	627	6.1	1.3	38
2013-07-08 16:30:00	105	170	0.34	0.072	0.84	0.86	0.42	16.8	1290	17.9	2.6	91
2013-07-27 13:00:00	19	21	0.073	0.055	1.9	1.2	0.23	11.5	243	1.2	0.8	13.7
2013-09-20 22:10:00	42	22	0.023	0.014	1.2	0.8	0.11	5.6	199	0.8	0.6	9
2014-04-29 7:10:00	48.8	35	0.08	0.03	1.36	0.56	0.21	12	1100	2.2	8.2	22
2014-05-15 10:50:00	16.8	57	0.12	0.051	1.14	0.71	0.19	13	934	2.23	2.3	17.3
2014-09-02 11:30:00	15.8	230	0.8	0.45	3.12	7	0.31	18	2820	6.91	4.3	42.4
2014-09-05 19:10:00	33.8	21	0.093	0.042	1.06	0.38	0.37	12	364	1.6	1	12
2014-09-10 16:00:00	27	120	0.3	0.085	1.19	0.84	0.4	18.6	2120	5.2	3.1	39
2014-09-21 5:50:00	24.6	30	0.095	0.055	1.46	0.45	0.2	9.7	381	2.61	1.2	16.4
2015-04-19 22:30:00	32	41	0.1	0.044	1.44	0.64	0.15	7.2	633	1.38	5.4	13.7
2015-07-19 15:10:00	22.4	84	0.35	0.21	1.45	2.2	0.1	18	1390	5.3	3	32
2015-08-10 12:10:00	31	93	0.23	0.082	1.16	0.65	0.46	10.3	1350	4.34	3.1	28
2015-09-29 12:30:00	26.6	110	0.3	0.16	1.45	0.38	0.41	10.5	1520	4.2	3.5	27.5
count	23	23	23	23	23	23	23	23	23	23	23	23
average	32.1	71.65	0.16	0.08	1.38	0.97	0.21	10.40	792.48	3.39	2.10	23.38
median	26.6	35.00	0.09	0.05	1.36	0.64	0.20	10.30	391.00	1.90	1.30	17.00
25th percentile	23.2	21.00	0.07	0.04	1.15	0.45	0.10	6.25	264.50	1.31	0.75	12.85
75th percentile	34.4	101.50	0.20	0.07	1.46	0.82	0.27	13.15	1320.00	4.77	3.05	30.00
WQ Guideline	-	25	0.03	-	3*	-	0.2	5	300	1	25	20

*Water quality guideline for Nitrate used

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

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)	(%)
2012-07-31 11:50:00	110	35	114.95	10058	51.71	5688	4370	43.4
2012-08-09 9:00:00	11	45	147.79	12932	87.75	965	11967	92.5
2012-08-11 5:30:00	21	11	36.13	3161	16.04	337	2824	89.3
2012-09-04 9:10:00	13	25.2	82.76	7242	2.26	29	7212	99.6
2012-10-23 2:00:00	3	25.6	84.08	7357	24.82	74	7282	99.0
2012-10-28 9:10:00	6	28.4	93.27	8161	6.46	39	8123	99.5
2013-05-10 8:40:00	32	24	78.82	6897	9.03	289	6608	95.8
2013-05-28 16:10:00	340	25	82.11	7184	9.96	3386	3798	52.9
2013-06-16 5:00:00	47	14.8	48.61	4253	5.08	239	4015	94.4
2013-07-05 6:10:00	31	60.2	197.71	17300	86.03	2667	14633	84.6
2013-07-08 16:30:00	170	105	430.60	37678	250.97	42664	-4986	-13.2
2013-07-27 13:00:00	21	19	62.40	5460	0.78	16	5444	99.7
2013-09-20 22:10:00	22	42	137.94	12070	51.82	1140	10930	90.6
2014-04-29 7:10:00	35	48.8	160.27	14024	91.41	3199	10824	77.2
2014-05-15 10:50:00	57	16.8	55.18	4828	42.00	2394	2434	50.4
2014-09-02 11:30:00	230	15.8	51.89	4540	0.76	175	4365	96.1
2014-09-05 19:10:00	21	33.8	111.01	9713	31.42	660	9053	93.2
2014-09-10 16:00:00	120	27	88.67	7759	18.56	2228	5531	71.3
2014-09-21 5:50:00	30	24.6	80.79	7069	20.99	630	6440	91.1
2015-04-19 22:30:00	41	32	105.10	9196	79.71	3268	5928	64.5
2015-07-19 15:10:00	84	22.4	73.57	6437	12.76	1072	5366	83.4
2015-08-10 12:10:00	93	31	101.81	8909	20.99	1952	6957	78.1
2015-09-29 12:30:00	110	26.6	87.36	7644	16.58	1824	5820	76.1
count	23	23	23	23	23	23	23	23
average	71.65	32.1	109.3	9559.6	40.8	3258.1	6301.6	78.7
median	35.00	26.6	87.4	7644.1	21.0	1071.6	5927.6	89.3
25th percentile	21.00	23.2	76.1946	6667.0275	9.4944	263.7519	4367.708625	73.71183262
75th percentile	101.50	34.4	113.0	9885.6	51.8	2530.4	7702.4	95.1
WQ Guideline	25	N/A	N/A	N/A	N/A	N/A	N/A	N/A

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

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)	(%)
2012-07-31 11:50:00	0.13	35	114.95	34.485	51.71	6.722	27.763	80.5
2012-08-09 9:00:00	0.036	45	147.79	44.337	87.75	3.159	41.178	92.9
2012-08-11 5:30:00	0.056	11	36.13	10.838	16.04	0.898	9.940	91.7
2012-09-04 9:10:00	0.065	25.2	82.76	24.829	2.26	0.147	24.682	99.4
2012-10-23 2:00:00	0.034	25.6	84.08	25.223	24.82	0.844	24.379	96.7
2012-10-28 9:10:00	0.009	28.4	93.27	27.982	6.46	0.058	27.924	99.8
2013-05-10 8:40:00	0.065	24	78.82	23.647	9.03	0.587	23.060	97.5
2013-05-28 16:10:00	0.066	25	82.11	24.632	9.96	0.657	23.975	97.3
2013-06-16 5:00:00	0.16	14.8	48.61	14.582	5.08	0.812	13.770	94.4
2013-07-05 6:10:00	0.08	60.2	197.71	59.314	86.03	6.883	52.431	88.4
2013-07-08 16:30:00	0.34	105	430.60	129.181	250.97	85.328	43.853	33.9
2013-07-27 13:00:00	0.073	19	62.40	18.720	0.78	0.057	18.663	99.7
2013-09-20 22:10:00	0.023	42	137.94	41.382	51.82	1.192	40.190	97.1
2014-04-29 7:10:00	0.08	48.8	160.27	48.081	91.41	7.313	40.768	84.8
2014-05-15 10:50:00	0.12	16.8	55.18	16.553	42.00	5.040	11.513	69.6
2014-09-02 11:30:00	0.8	15.8	51.89	15.567	0.76	0.610	14.958	96.1
2014-09-05 19:10:00	0.093	33.8	111.01	33.302	31.42	2.922	30.381	91.2
2014-09-10 16:00:00	0.3	27	88.67	26.602	18.56	5.569	21.033	79.1
2014-09-21 5:50:00	0.095	24.6	80.79	24.238	20.99	1.994	22.244	91.8
2015-04-19 22:30:00	0.1	32	105.10	31.529	79.71	7.971	23.557	74.7
2015-07-19 15:10:00	0.35	22.4	73.57	22.070	12.76	4.465	17.605	79.8
2015-08-10 12:10:00	0.23	31	101.81	30.544	20.99	4.827	25.716	84.2
2015-09-29 12:30:00	0.3	26.6	87.36	26.208	16.58	4.975	21.233	81.0
count	23	23	114.95	34.485	51.71	6.722	27.763	80.5
average	0.16	32.1	147.79	44.337	87.75	3.159	41.178	92.9
median	0.09	26.6	36.13	10.838	16.04	0.898	9.940	91.7
25th percentile	0.07	23.2	82.76	24.829	2.26	0.147	24.682	99.4
75th percentile	0.20	34.4	84.08	25.223	24.82	0.844	24.379	96.7
WQ Guideline	0.03	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Table D-6: Water Quality Performance for Ortho-Phosphate (PO_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)	(%)
2012-07-31 11:50:00	0.052	35	114.95	8.046	51.71	2.689	5.358	66.6
2012-08-09 9:00:00	0.035	45	147.79	10.345	87.75	3.071	7.274	70.3
2012-08-11 5:30:00	0.037	11	36.13	2.529	16.04	0.594	1.935	76.5
2012-09-04 9:10:00	0.035	25.2	82.76	5.793	2.26	0.079	5.714	98.6
2012-10-23 2:00:00	0.038	25.6	84.08	5.885	24.82	0.943	4.942	84.0
2012-10-28 9:10:00	0.023	28.4	93.27	6.529	6.46	0.149	6.380	97.7
2013-05-10 8:40:00	0.02	24	78.82	5.518	9.03	0.181	5.337	96.7
2013-05-28 16:10:00	0.032	25	82.11	5.747	9.96	0.319	5.429	94.5
2013-06-16 5:00:00	0.063	14.8	48.61	3.402	5.08	0.320	3.083	90.6
2013-07-05 6:10:00	0.046	60.2	197.71	13.840	86.03	3.957	9.882	71.4
2013-07-08 16:30:00	0.072	105	430.60	30.142	250.97	18.069	12.073	40.1
2013-07-27 13:00:00	0.055	19	62.40	4.368	0.78	0.043	4.325	99.0
2013-09-20 22:10:00	0.014	42	137.94	9.656	51.82	0.725	8.930	92.5
2014-04-29 7:10:00	0.03	48.8	160.27	11.219	91.41	2.742	8.477	75.6
2014-05-15 10:50:00	0.051	16.8	55.18	3.862	42.00	2.142	1.720	44.5
2014-09-02 11:30:00	0.45	15.8	51.89	3.632	0.76	0.343	3.289	90.6
2014-09-05 19:10:00	0.042	33.8	111.01	7.771	31.42	1.319	6.451	83.0
2014-09-10 16:00:00	0.085	27	88.67	6.207	18.56	1.578	4.629	74.6
2014-09-21 5:50:00	0.055	24.6	80.79	5.655	20.99	1.155	4.501	79.6
2015-04-19 22:30:00	0.044	32	105.10	7.357	79.71	3.507	3.849	52.3
2015-07-19 15:10:00	0.21	22.4	73.57	5.150	12.76	2.679	2.471	48.0
2015-08-10 12:10:00	0.082	31	101.81	7.127	20.99	1.721	5.406	75.9
2015-09-29 12:30:00	0.16	26.6	87.36	6.115	16.58	2.654	3.462	56.6
count	23	23	23	23	23	23	23	23
average	0.08	32.1	109.3	7.6	40.8	2.2	5.4	76.5
median	0.05	26.6	87.4	6.1	21.0	1.3	5.3	76.5
25th percentile	0.04	23.2	76.1946	5.333622	9.4944	0.3313251	3.65551635	68.44876024
75th percentile	0.07	34.4	113.0	7.9	51.8	2.7	6.4	91.5
WQ Guideline	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)

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)	(%)
2012-07-31 11:50:00	1.5	35	114.95	71.268	51.71	77.561	-6.293	-8.8
2012-08-09 9:00:00	1.4	45	147.79	91.631	87.75	122.847	-31.217	-34.1
2012-08-11 5:30:00	1	11	36.13	22.399	16.04	16.043	6.355	28.4
2012-09-04 9:10:00	1.7	25.2	82.76	51.313	2.26	3.850	47.463	92.5
2012-10-23 2:00:00	1.4	25.6	84.08	52.128	24.82	34.752	17.375	33.3
2012-10-28 9:10:00	1.1	28.4	93.27	57.829	6.46	7.111	50.718	87.7
2013-05-10 8:40:00	1.3	24	78.82	48.870	9.03	11.739	37.131	76.0
2013-05-28 16:10:00	1.5	25	82.11	50.906	9.96	14.938	35.968	70.7
2013-06-16 5:00:00	1.2	14.8	48.61	30.136	5.08	6.090	24.046	79.8
2013-07-05 6:10:00	0.97	60.2	197.71	122.581	86.03	83.451	39.130	31.9
2013-07-08 16:30:00	0.84	105	430.60	266.974	250.97	210.811	56.163	21.0
2013-07-27 13:00:00	1.9	19	62.40	38.688	0.78	1.483	37.205	96.2
2013-09-20 22:10:00	1.2	42	137.94	85.522	51.82	62.182	23.340	27.3
2014-04-29 7:10:00	1.36	48.8	160.27	99.368	91.41	124.322	-24.953	-25.1
2014-05-15 10:50:00	1.14	16.8	55.18	34.209	42.00	47.876	-13.667	-40.0
2014-09-02 11:30:00	3.12	15.8	51.89	32.173	0.76	2.377	29.795	92.6
2014-09-05 19:10:00	1.06	33.8	111.01	68.825	31.42	33.301	35.524	51.6
2014-09-10 16:00:00	1.19	27	88.67	54.978	18.56	22.091	32.887	59.8
2014-09-21 5:50:00	1.46	24.6	80.79	50.091	20.99	30.647	19.445	38.8
2015-04-19 22:30:00	1.44	32	105.10	65.160	79.71	114.788	-49.629	-76.2
2015-07-19 15:10:00	1.45	22.4	73.57	45.612	12.76	18.498	27.114	59.4
2015-08-10 12:10:00	1.16	31	101.81	63.123	20.99	24.345	38.778	61.4
2015-09-29 12:30:00	1.45	26.6	87.36	54.164	16.58	24.048	30.116	55.6
count	23	23	23	23	23	23	23	23
average	1.38	32.1	109.3	67.7	40.8	47.6	20.1	38.3
median	1.36	26.6	87.4	54.2	21.0	24.3	29.8	51.6
25th percentile	1.15	23.2	76.1946	47.240652	9.4944	13.3386	11.8651605	24.16400383
75th percentile	1.46	34.4	113.0	70.0	51.8	69.9	37.2	73.3
WQ Guideline*	3[a]	N/A	N/A	N/A	N/A	N/A	N/A	N/A

***Water quality guideline for Nitrate used**

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

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)	(%)
2012-07-31 11:50:00	1.2	35	114.95	172.423	51.71	62.049	110.374	64.0
2012-08-09 9:00:00	0.57	45	147.79	221.687	87.75	50.016	171.670	77.4
2012-08-11 5:30:00	0.3	11	36.13	54.190	16.04	4.813	49.377	91.1
2012-09-04 9:10:00	0.62	25.2	82.76	124.145	2.26	1.404	122.740	98.9
2012-10-23 2:00:00	0.65	25.6	84.08	126.115	24.82	16.135	109.980	87.2
2012-10-28 9:10:00	0.15	28.4	93.27	139.909	6.46	0.970	138.939	99.3
2013-05-10 8:40:00	0.67	24	78.82	118.233	9.03	6.050	112.183	94.9
2013-05-28 16:10:00	0.45	25	82.11	123.159	9.96	4.481	118.678	96.4
2013-06-16 5:00:00	0.44	14.8	48.61	72.910	5.08	2.233	70.677	96.9
2013-07-05 6:10:00	0.55	60.2	197.71	296.568	86.03	47.318	249.250	84.0
2013-07-08 16:30:00	0.86	105	430.60	645.905	250.97	215.830	430.075	66.6
2013-07-27 13:00:00	1.2	19	62.40	93.601	0.78	0.937	92.664	99.0
2013-09-20 22:10:00	0.8	42	137.94	206.908	51.82	41.455	165.453	80.0
2014-04-29 7:10:00	0.56	48.8	160.27	240.407	91.41	51.191	189.216	78.7
2014-05-15 10:50:00	0.71	16.8	55.18	82.763	42.00	29.817	52.946	64.0
2014-09-02 11:30:00	7	15.8	51.89	77.837	0.76	5.334	72.503	93.1
2014-09-05 19:10:00	0.38	33.8	111.01	166.511	31.42	11.938	154.573	92.8
2014-09-10 16:00:00	0.84	27	88.67	133.012	18.56	15.594	117.418	88.3
2014-09-21 5:50:00	0.45	24.6	80.79	121.189	20.99	9.446	111.743	92.2
2015-04-19 22:30:00	0.64	32	105.10	157.644	79.71	51.017	106.627	67.6
2015-07-19 15:10:00	2.2	22.4	73.57	110.351	12.76	28.066	82.285	74.6
2015-08-10 12:10:00	0.65	31	101.81	152.718	20.99	13.642	139.076	91.1
2015-09-29 12:30:00	0.38	26.6	87.36	131.042	16.58	6.302	124.739	95.2
count	23	23	23	23	23	23	23	23
average	0.97	32.1	109.3	163.9	40.8	29.4	134.5	85.8
median	0.64	26.6	87.4	131.0	21.0	13.6	117.4	91.1
25th percentile	0.45	23.2	76.1946	114.2919	9.4944	5.07351	99.6456585	78.07232662
75th percentile	0.82	34.4	113.0	169.5	51.8	44.4	146.8	95.0
WQ Guideline	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)

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)	(%)
2012-07-31 11:50:00	0.16	35	114.95	0.0471	51.71	0.0083	0.0389	82.4
2012-08-09 9:00:00	0.09	45	147.79	0.0606	87.75	0.0079	0.0527	87.0
2012-08-11 5:30:00	0.05	11	36.13	0.0148	16.04	0.0008	0.0140	94.6
2012-09-04 9:10:00	0.1	25.2	82.76	0.0339	2.26	0.0002	0.0337	99.3
2012-10-23 2:00:00	0.09	25.6	84.08	0.0345	24.82	0.0022	0.0322	93.5
2012-10-28 9:10:00	0.09	28.4	93.27	0.0382	6.46	0.0006	0.0377	98.5
2013-05-10 8:40:00	0.1	24	78.82	0.0323	9.03	0.0009	0.0314	97.2
2013-05-28 16:10:00	0.21	25	82.11	0.0337	9.96	0.0021	0.0316	93.8
2013-06-16 5:00:00	0.2	14.8	48.61	0.0199	5.08	0.0010	0.0189	94.9
2013-07-05 6:10:00	0.2	60.2	197.71	0.0811	86.03	0.0172	0.0639	78.8
2013-07-08 16:30:00	0.42	105	430.60	0.1765	250.97	0.1054	0.0711	40.3
2013-07-27 13:00:00	0.23	19	62.40	0.0256	0.78	0.0002	0.0254	99.3
2013-09-20 22:10:00	0.11	42	137.94	0.0566	51.82	0.0057	0.0509	89.9
2014-04-29 7:10:00	0.21	48.8	160.27	0.0657	91.41	0.0192	0.0465	70.8
2014-05-15 10:50:00	0.19	16.8	55.18	0.0226	42.00	0.0080	0.0146	64.7
2014-09-02 11:30:00	0.31	15.8	51.89	0.0213	0.76	0.0002	0.0210	98.9
2014-09-05 19:10:00	0.37	33.8	111.01	0.0455	31.42	0.0116	0.0339	74.5
2014-09-10 16:00:00	0.4	27	88.67	0.0364	18.56	0.0074	0.0289	79.6
2014-09-21 5:50:00	0.2	24.6	80.79	0.0331	20.99	0.0042	0.0289	87.3
2015-04-19 22:30:00	0.15	32	105.10	0.0431	79.71	0.0120	0.0311	72.3
2015-07-19 15:10:00	0.1	22.4	73.57	0.0302	12.76	0.0013	0.0289	95.8
2015-08-10 12:10:00	0.46	31	101.81	0.0417	20.99	0.0097	0.0321	76.9
2015-09-29 12:30:00	0.41	26.6	87.36	0.0358	16.58	0.0068	0.0290	81.0
count	23	23	23	23	23	23	23	23
average	0.21	32.1	109.3	0.0	40.8	0.0	0.0	84.8
median	0.20	26.6	87.4	0.0	21.0	0.0	0.0	87.3
25th percentile	0.10	23.2	76.1946	0.031239786	9.4944	0.00095904	0.028906789	77.82293548
75th percentile	0.27	34.4	113.0	0.0	51.8	0.0	0.0	95.3
WQ Guideline	0.2	N/A	N/A	N/A	N/A	N/A	N/A	N/A

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

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)	(%)
2012-07-31 11:50:00	8.6	35	114.95	2.069	51.71	0.445	1.624	78.5
2012-08-09 9:00:00	5.3	45	147.79	2.660	87.75	0.465	2.195	82.5
2012-08-11 5:30:00	4.7	11	36.13	0.650	16.04	0.075	0.575	88.4
2012-09-04 9:10:00	3.4	25.2	82.76	1.490	2.26	0.008	1.482	99.5
2012-10-23 2:00:00	5.1	25.6	84.08	1.513	24.82	0.127	1.387	91.6
2012-10-28 9:10:00	5.1	28.4	93.27	1.679	6.46	0.033	1.646	98.0
2013-05-10 8:40:00	14.7	24	78.82	1.419	9.03	0.133	1.286	90.6
2013-05-28 16:10:00	8.8	25	82.11	1.478	9.96	0.088	1.390	94.1
2013-06-16 5:00:00	13.3	14.8	48.61	0.875	5.08	0.068	0.807	92.3
2013-07-05 6:10:00	6.9	60.2	197.71	3.559	86.03	0.594	2.965	83.3
2013-07-08 16:30:00	16.8	105	430.60	7.751	250.97	4.216	3.535	45.6
2013-07-27 13:00:00	11.5	19	62.40	1.123	0.78	0.009	1.114	99.2
2013-09-20 22:10:00	5.6	42	137.94	2.483	51.82	0.290	2.193	88.3
2014-04-29 7:10:00	12	48.8	160.27	2.885	91.41	1.097	1.788	62.0
2014-05-15 10:50:00	13	16.8	55.18	0.993	42.00	0.546	0.447	45.0
2014-09-02 11:30:00	18	15.8	51.89	0.934	0.76	0.014	0.920	98.5
2014-09-05 19:10:00	12	33.8	111.01	1.998	31.42	0.377	1.621	81.1
2014-09-10 16:00:00	18.6	27	88.67	1.596	18.56	0.345	1.251	78.4
2014-09-21 5:50:00	9.7	24.6	80.79	1.454	20.99	0.204	1.251	86.0
2015-04-19 22:30:00	7.2	32	105.10	1.892	79.71	0.574	1.318	69.7
2015-07-19 15:10:00	18	22.4	73.57	1.324	12.76	0.230	1.095	82.7
2015-08-10 12:10:00	10.3	31	101.81	1.833	20.99	0.216	1.616	88.2
2015-09-29 12:30:00	10.5	26.6	87.36	1.572	16.58	0.174	1.398	88.9
count	23	23	23	23	23	23	23	23
average	10.40	32.1	109.3	2.0	40.8	0.4	1.5	83.2
median	10.30	26.6	87.4	1.6	21.0	0.2	1.4	88.2
25th percentile	6.25	23.2	76.1946	1.3715028	9.4944	0.08152071	1.1824449	79.82047624
75th percentile	13.15	34.4	113.0	2.0	51.8	0.5	1.6	92.0
WQ Guideline	5	N/A	N/A	N/A	N/A	N/A	N/A	N/A

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

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)	(%)
2012-07-31 11:50:00	1350	35	114.95	N/A	51.71	69.80499	N/A	N/A
2012-08-09 9:00:00	223	45	147.79	N/A	87.75	19.5678486	N/A	N/A
2012-08-11 5:30:00	286	11	36.13	N/A	16.04	4.5884124	N/A	N/A
2012-09-04 9:10:00	211	25.2	82.76	N/A	2.26	0.477915	N/A	N/A
2012-10-23 2:00:00	62	25.6	84.08	N/A	24.82	1.5390384	N/A	N/A
2012-10-28 9:10:00	118	28.4	93.27	N/A	6.46	0.76287	N/A	N/A
2013-05-10 8:40:00	391	24	78.82	N/A	9.03	3.53073	N/A	N/A
2013-05-28 16:10:00	308	25	82.11	N/A	9.96	3.0673104	N/A	N/A
2013-06-16 5:00:00	307	14.8	48.61	N/A	5.08	1.5581478	N/A	N/A
2013-07-05 6:10:00	627	60.2	197.71	N/A	86.03	53.9421894	N/A	N/A
2013-07-08 16:30:00	1290	105	430.60	N/A	250.97	323.74485	N/A	N/A
2013-07-27 13:00:00	243	19	62.40	N/A	0.78	0.1896858	N/A	N/A
2013-09-20 22:10:00	199	42	137.94	N/A	51.82	10.3118616	N/A	N/A
2014-04-29 7:10:00	1100	48.8	160.27	N/A	91.41	100.5543	N/A	N/A
2014-05-15 10:50:00	934	16.8	55.18	N/A	42.00	39.2246376	N/A	N/A
2014-09-02 11:30:00	2820	15.8	51.89	N/A	0.76	2.14884	N/A	N/A
2014-09-05 19:10:00	364	33.8	111.01	N/A	31.42	11.435424	N/A	N/A
2014-09-10 16:00:00	2120	27	88.67	N/A	18.56	39.35568	N/A	N/A
2014-09-21 5:50:00	381	24.6	80.79	N/A	20.99	7.997571	N/A	N/A
2015-04-19 22:30:00	633	32	105.10	N/A	79.71	50.4590886	N/A	N/A
2015-07-19 15:10:00	1390	22.4	73.57	N/A	12.76	17.732508	N/A	N/A
2015-08-10 12:10:00	1350	31	101.81	N/A	20.99	28.33299	N/A	N/A
2015-09-29 12:30:00	1520	26.6	87.36	N/A	16.58	25.208592	N/A	N/A
count	23	23	23	0	23	23	0	0
average	792.48	32.1	109.3	N/A	40.8	35.4580644	N/A	N/A
median	792.48	26.6	87.4	N/A	21.0	11.435424	N/A	N/A
25th percentile	264.5	23.2	76.1946	N/A	9.4944	2.6080752	N/A	N/A
75th percentile	1320	34.4	113.0	N/A	51.8	36.5017257	N/A	N/A
WQ Guideline	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

*Insufficient data in database to calculate influent load

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

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)	(%)
2012-07-31 11:50:00	6.13	35	114.95	1.931	51.71	0.317	1.614	83.6
2012-08-09 9:00:00	1.9	45	147.79	2.483	87.75	0.167	2.316	93.3
2012-08-11 5:30:00	1.24	11	36.13	0.607	16.04	0.020	0.587	96.7
2012-09-04 9:10:00	0.94	25.2	82.76	1.390	2.26	0.002	1.388	99.8
2012-10-23 2:00:00	0.3	25.6	84.08	1.412	24.82	0.007	1.405	99.5
2012-10-28 9:10:00	0.5	28.4	93.27	1.567	6.46	0.003	1.564	99.8
2013-05-10 8:40:00	1.82	24	78.82	1.324	9.03	0.016	1.308	98.8
2013-05-28 16:10:00	1.57	25	82.11	1.379	9.96	0.016	1.364	98.9
2013-06-16 5:00:00	1.5	14.8	48.61	0.817	5.08	0.008	0.809	99.1
2013-07-05 6:10:00	6.1	60.2	197.71	3.322	86.03	0.525	2.797	84.2
2013-07-08 16:30:00	17.9	105	430.60	7.234	250.97	4.492	2.742	37.9
2013-07-27 13:00:00	1.2	19	62.40	1.048	0.78	0.001	1.047	99.9
2013-09-20 22:10:00	0.8	42	137.94	2.317	51.82	0.041	2.276	98.2
2014-04-29 7:10:00	2.2	48.8	160.27	2.693	91.41	0.201	2.491	92.5
2014-05-15 10:50:00	2.23	16.8	55.18	0.927	42.00	0.094	0.833	89.9
2014-09-02 11:30:00	6.91	15.8	51.89	0.872	0.76	0.005	0.867	99.4
2014-09-05 19:10:00	1.6	33.8	111.01	1.865	31.42	0.050	1.815	97.3
2014-09-10 16:00:00	5.2	27	88.67	1.490	18.56	0.097	1.393	93.5
2014-09-21 5:50:00	2.61	24.6	80.79	1.357	20.99	0.055	1.303	96.0
2015-04-19 22:30:00	1.38	32	105.10	1.766	79.71	0.110	1.656	93.8
2015-07-19 15:10:00	5.3	22.4	73.57	1.236	12.76	0.068	1.168	94.5
2015-08-10 12:10:00	4.34	31	101.81	1.710	20.99	0.091	1.619	94.7
2015-09-29 12:30:00	4.2	26.6	87.36	1.468	16.58	0.070	1.398	95.3
count	23	23	23	23	23	23	23	23
average	3.39	32.1	109.3	1.8	40.8	0.3	1.6	92.9
median	1.90	26.6	87.4	1.5	21.0	0.1	1.4	96.0
25th percentile	1.31	23.2	76.1946	1.28006928	9.4944	0.011624208	1.235422065	93.40266415
75th percentile	4.77	34.4	113.0	1.9	51.8	0.1	1.7	99.0
WQ Guideline	1	N/A	N/A	N/A	N/A	N/A	N/A	N/A

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

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)	(%)
2012-07-31 11:50:00	2.2	35	114.95	1.149	51.71	0.114	1.036	90.1
2012-08-09 9:00:00	0.9	45	147.79	1.478	87.75	0.079	1.399	94.7
2012-08-11 5:30:00	0.7	11	36.13	0.361	16.04	0.011	0.350	96.9
2012-09-04 9:10:00	0.5	25.2	82.76	0.828	2.26	0.001	0.826	99.9
2012-10-23 2:00:00	0.2	25.6	84.08	0.841	24.82	0.005	0.836	99.4
2012-10-28 9:10:00	0.5	28.4	93.27	0.933	6.46	0.003	0.929	99.7
2013-05-10 8:40:00	1	24	78.82	0.788	9.03	0.009	0.779	98.9
2013-05-28 16:10:00	1.3	25	82.11	0.821	9.96	0.013	0.808	98.4
2013-06-16 5:00:00	0.7	14.8	48.61	0.486	5.08	0.004	0.483	99.3
2013-07-05 6:10:00	1.3	60.2	197.71	1.977	86.03	0.112	1.865	94.3
2013-07-08 16:30:00	2.6	105	430.60	4.306	250.97	0.653	3.654	84.8
2013-07-27 13:00:00	0.8	19	62.40	0.624	0.78	0.001	0.623	99.9
2013-09-20 22:10:00	0.6	42	137.94	1.379	51.82	0.031	1.348	97.7
2014-04-29 7:10:00	8.2	48.8	160.27	1.603	91.41	0.750	0.853	53.2
2014-05-15 10:50:00	2.3	16.8	55.18	0.552	42.00	0.097	0.455	82.5
2014-09-02 11:30:00	4.3	15.8	51.89	0.519	0.76	0.003	0.516	99.4
2014-09-05 19:10:00	1	33.8	111.01	1.110	31.42	0.031	1.079	97.2
2014-09-10 16:00:00	3.1	27	88.67	0.887	18.56	0.058	0.829	93.5
2014-09-21 5:50:00	1.2	24.6	80.79	0.808	20.99	0.025	0.783	96.9
2015-04-19 22:30:00	5.4	32	105.10	1.051	79.71	0.430	0.621	59.0
2015-07-19 15:10:00	3	22.4	73.57	0.736	12.76	0.038	0.697	94.8
2015-08-10 12:10:00	3.1	31	101.81	1.018	20.99	0.065	0.953	93.6
2015-09-29 12:30:00	3.5	26.6	87.36	0.874	16.58	0.058	0.816	93.4
count	23	23	23	23	23	23	23	23
average	2.10	32.1	109.3	1.1	40.8	0.1	1.0	92.1
median	1.30	26.6	87.4	0.9	21.0	0.0	0.8	96.9
25th percentile	0.75	23.2	76.1946	0.761946	9.4944	0.00699732	0.66039171	93.43288965
75th percentile	3.05	34.4	113.0	1.1	51.8	0.1	1.0	99.1
WQ Guideline	25	N/A	N/A	N/A	N/A	N/A	N/A	N/A

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

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)	(%)
2012-07-31 11:50:00	43.3	35	114.95	12.644	51.71	2.239	10.405	0.001611
2012-08-09 9:00:00	14	45	147.79	16.257	87.75	1.228	15.029	0.002326
2012-08-11 5:30:00	11.3	11	36.13	3.974	16.04	0.181	3.793	0.000587
2012-09-04 9:10:00	9	25.2	82.76	9.104	2.26	0.020	9.084	0.001406
2012-10-23 2:00:00	4	25.6	84.08	9.248	24.82	0.099	9.149	0.001416
2012-10-28 9:10:00	6	28.4	93.27	10.260	6.46	0.039	10.221	0.001582
2013-05-10 8:40:00	17.1	24	78.82	8.670	9.03	0.154	8.516	0.001318
2013-05-28 16:10:00	17	25	82.11	9.032	9.96	0.169	8.862	0.001372
2013-06-16 5:00:00	14	14.8	48.61	5.347	5.08	0.071	5.276	0.000817
2013-07-05 6:10:00	38	60.2	197.71	21.748	86.03	3.269	18.479	0.002861
2013-07-08 16:30:00	91	105	430.60	47.366	250.97	22.838	24.529	0.003797
2013-07-27 13:00:00	13.7	19	62.40	6.864	0.78	0.011	6.853	0.001061
2013-09-20 22:10:00	9	42	137.94	15.173	51.82	0.466	14.707	0.002277
2014-04-29 7:10:00	22	48.8	160.27	17.630	91.41	2.011	15.619	0.002418
2014-05-15 10:50:00	17.3	16.8	55.18	6.069	42.00	0.727	5.343	0.000827
2014-09-02 11:30:00	42.4	15.8	51.89	5.708	0.76	0.032	5.676	0.000879
2014-09-05 19:10:00	12	33.8	111.01	12.211	31.42	0.377	11.834	0.001832
2014-09-10 16:00:00	39	27	88.67	9.754	18.56	0.724	9.030	0.001398
2014-09-21 5:50:00	16.4	24.6	80.79	8.887	20.99	0.344	8.543	0.001322
2015-04-19 22:30:00	13.7	32	105.10	11.561	79.71	1.092	10.468	0.001621
2015-07-19 15:10:00	32	22.4	73.57	8.092	12.76	0.408	7.684	0.001189
2015-08-10 12:10:00	28	31	101.81	11.199	20.99	0.588	10.612	0.001643
2015-09-29 12:30:00	27.5	26.6	87.36	9.610	16.58	0.456	9.154	0.001417
count	23	23	23	23	23	23	23	23
average	23.38	32.1	109.3	12.0	40.8	1.6	10.4	0.0
median	17.00	26.6	87.4	9.6	21.0	0.4	9.1	0.0
25th percentile	12.85	23.2	76.1946	8.381406	9.4944	0.1268529	8.1000843	0.001253883
75th percentile	30.00	34.4	113.0	12.4	51.8	0.9	11.2	0.0
WQ Guideline	20	N/A	N/A	N/A	N/A	N/A	N/A	N/A

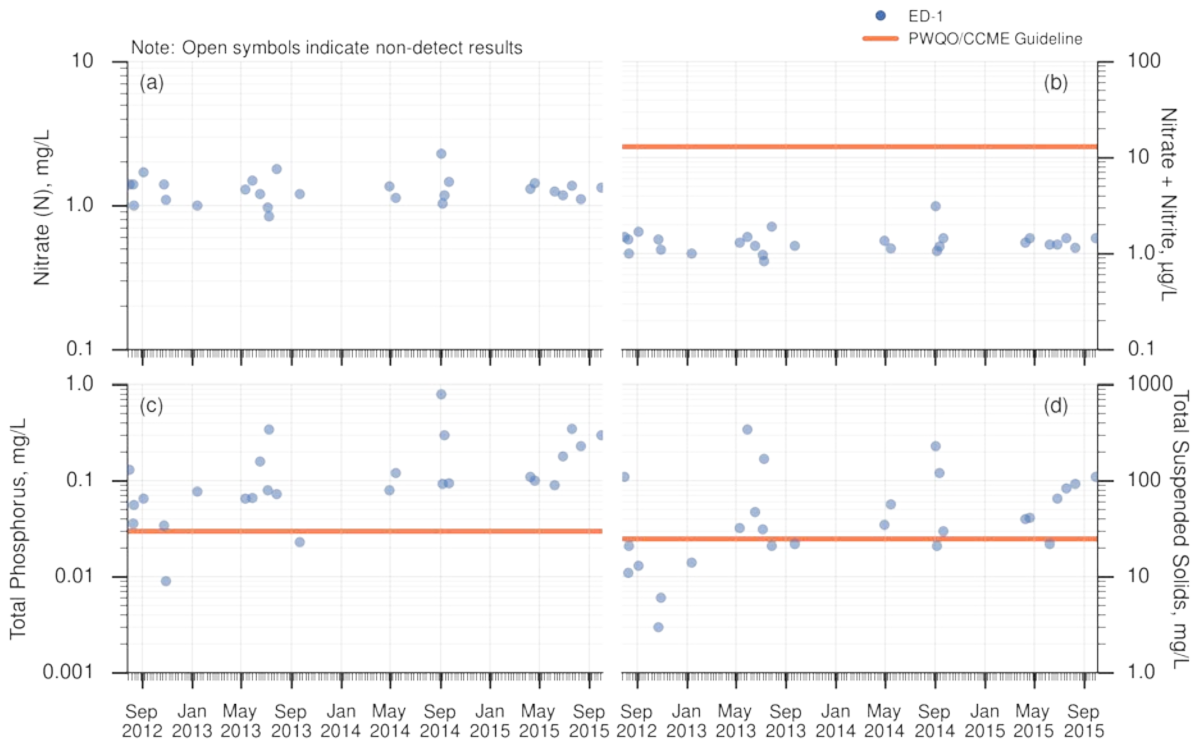


Figure D-1: Time series of effluent concentrations for selected parameters

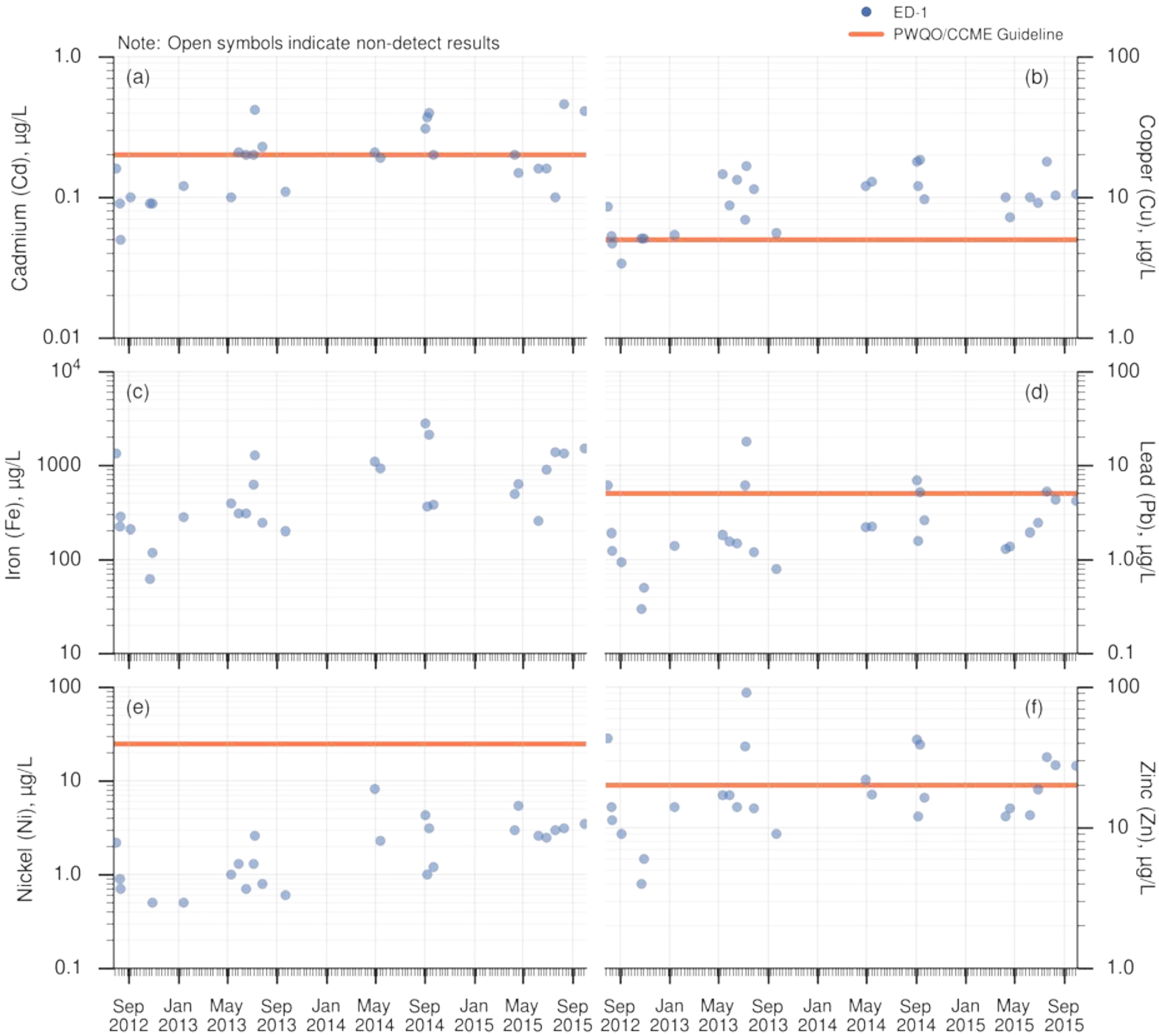


Figure D-2: Time series of effluent concentrations for selected metals

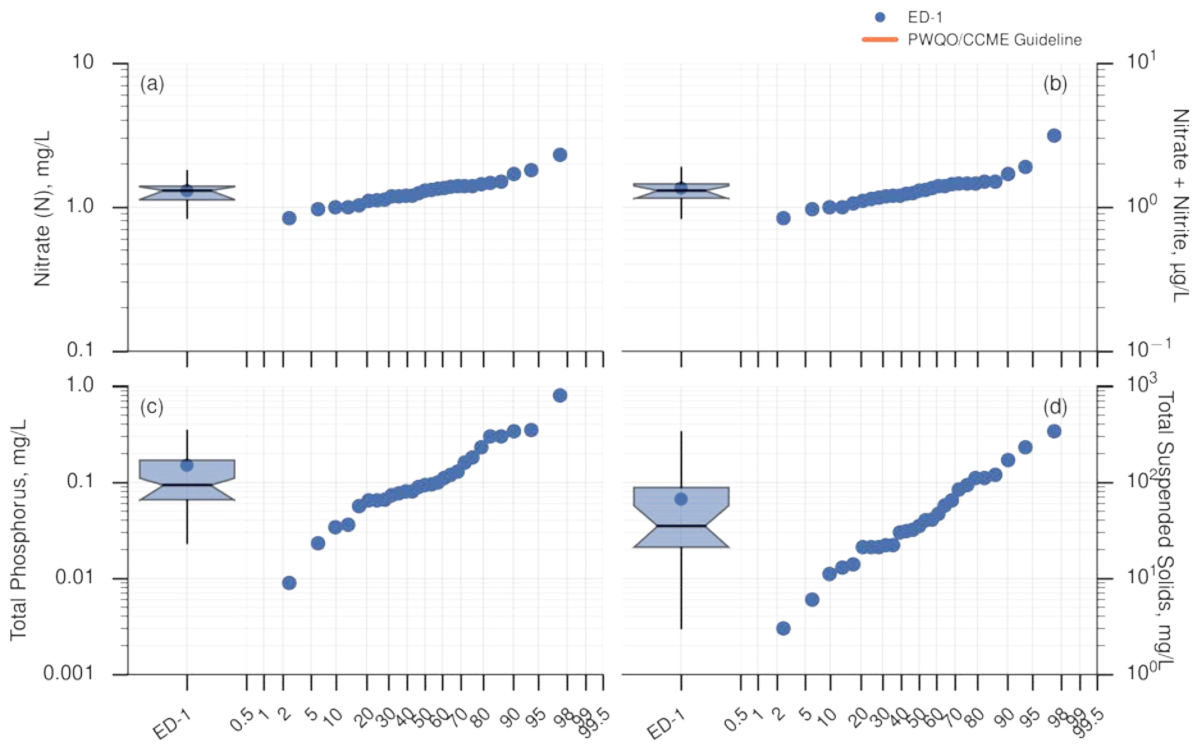


Figure D-3: Probability plots of effluent concentrations for selected parameters

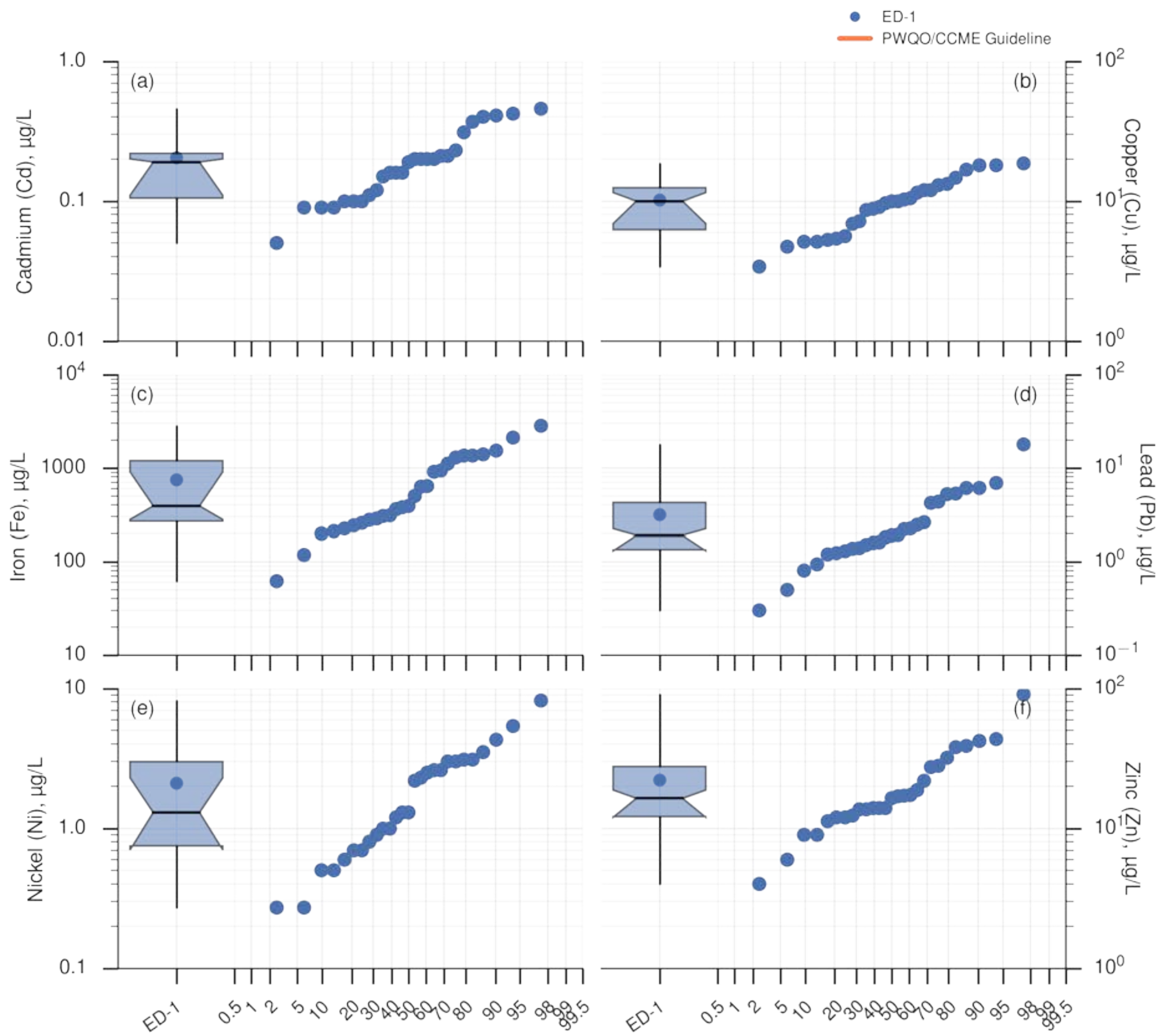


Figure D-4: Probability plots of effluent concentrations for selected metals

ELM DRIVE, CITY OF MISSISSAUGA

LOW IMPACT DEVELOPMENT INFRASTRUCTURE PERFORMANCE AND RISK MANAGEMENT ASSESSMENT

Appendix E
Site Maintenance and Inspection Logs

NOTICE

1 BIORETENTION MAINTENANCE

A brief description of maintenance activities for Elm Drive 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[1]:

- 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 (wood 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.

2 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

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

notes can be helpful in measuring loss of infiltration over time. Typical recommended maintenance activities for bioretention cells include:

- 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.

3 DOCUMENTATION OF MAINTENANCE ACTIVITIES AND COSTS

Because of the significance of maintenance over the life of a 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 Elm Drive. 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 checklist is completed (biweekly in the spring, summer, and fall, monthly in winter) 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.

4 SITE INSPECTION LOG

Below is the checklist template used by monitoring staff to note maintenance needs during routine site visits. A photo log is also kept to supplement this information.

LID Inspection Checklist

Site: Elm Drive

Inspector: ______________________________

Date: __________________________________

Site Characteristics:

Elm Drive Bioretention Cells	
Drainage Area	Road, parking layby and sidewalk
Soil Media	Engineered bioretention mix
Pre-treatment	Permeable pavement and grass swale
Hydraulic Configuration	Online
Inlet Type	Inlet pipes from parking layby and permeable pavement sidewalk

		Category:	**Notes:**
Contributing Drainage Area:			
% 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% --- 5% --- 10% --- 15% --- 20% +		
% 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	______________________		

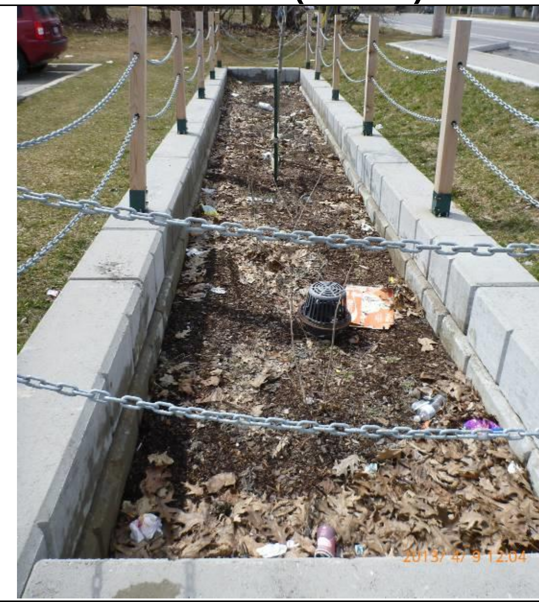
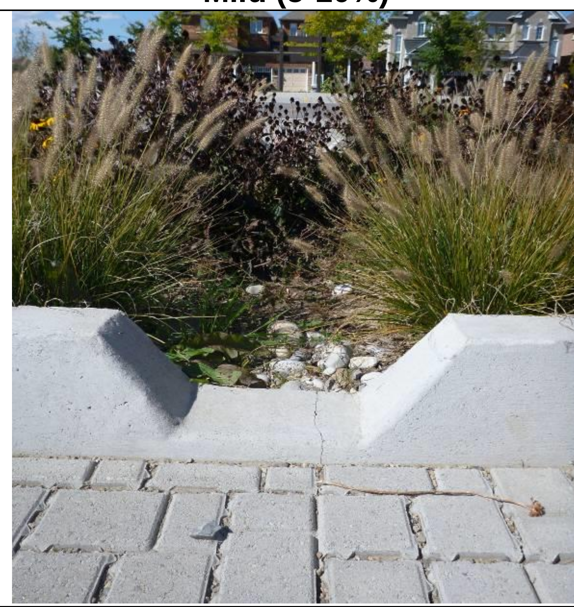
Maintenance:			
Is maintenance required?	Yes or No		
What needs to be done?	________________________		
How much time was spent on maintenance?	________________________		
Regular maintenance, long-term maintenance or emergency maintenance?	________________________		
Who is responsible?	________________________		
How often is regular maintenance done?	________________________		

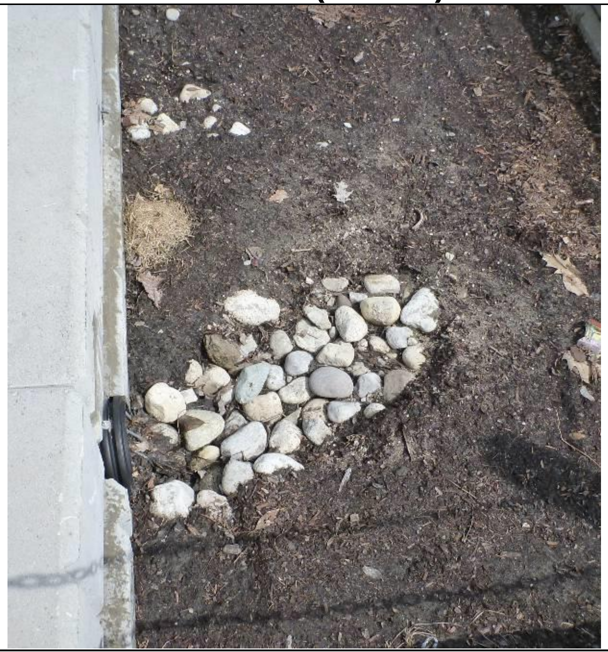
Photos:

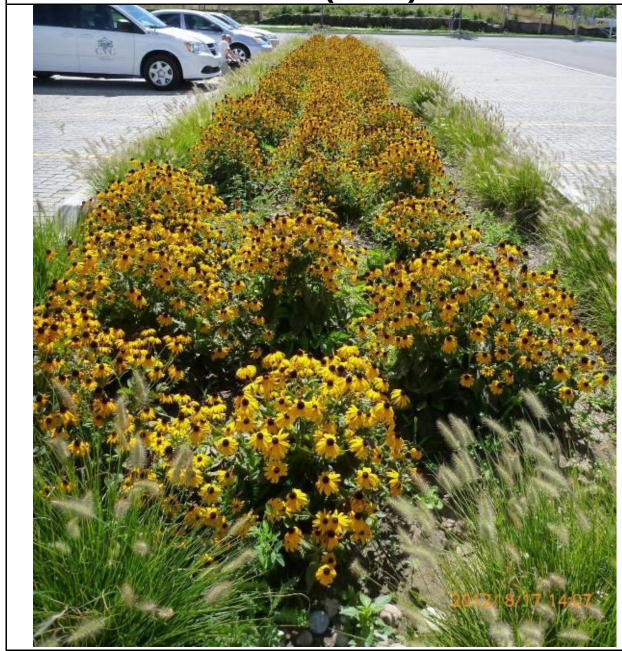
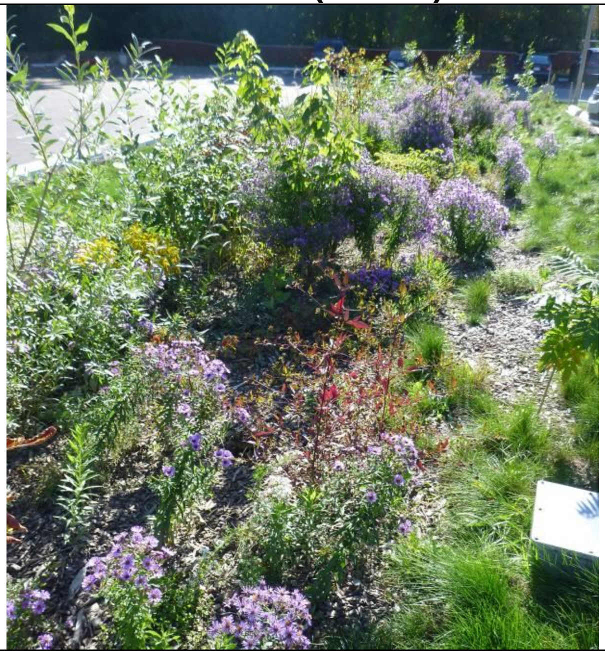
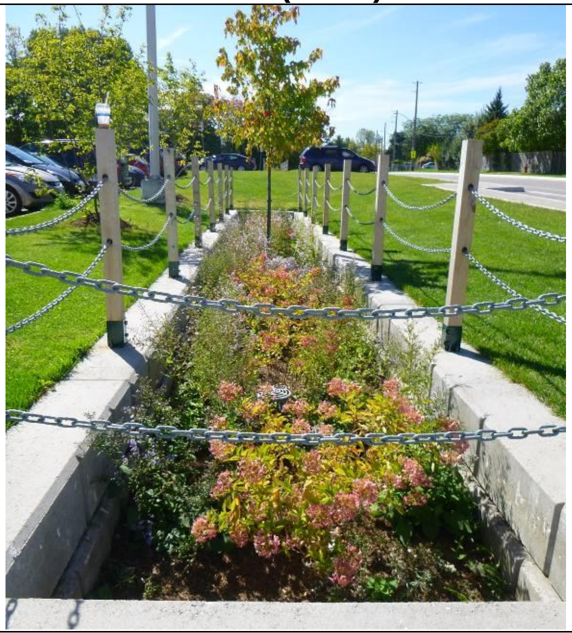
Number of Photo	Description/Notes

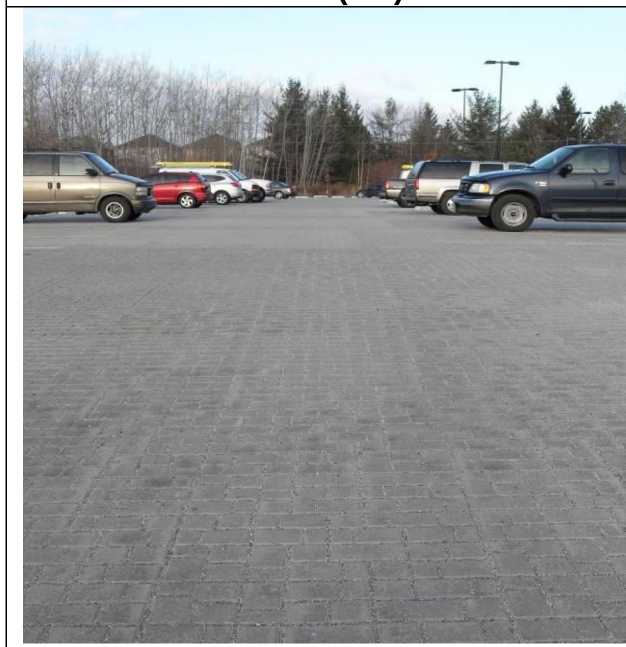
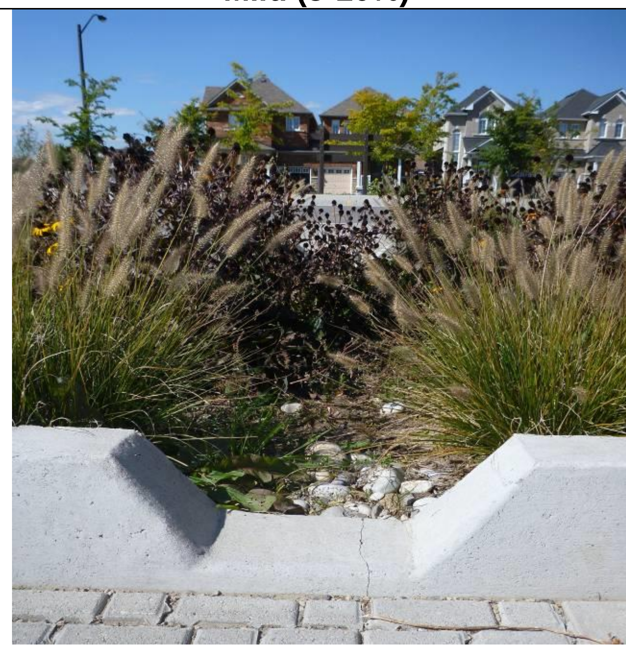
Site Comments:

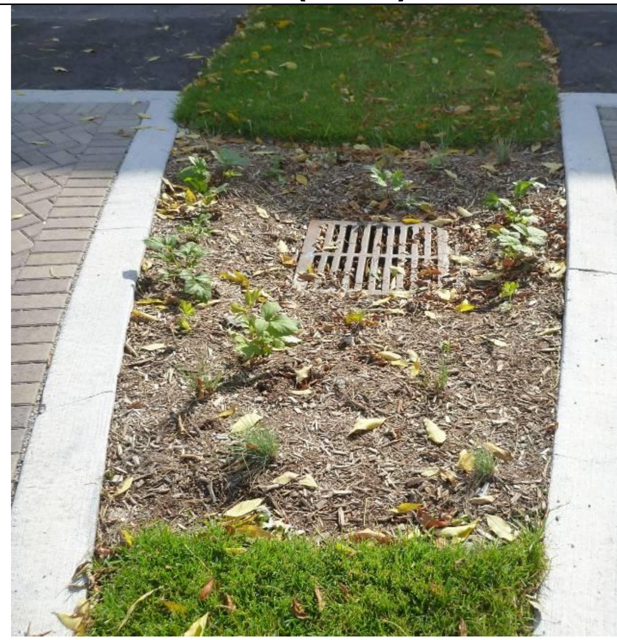
LID Inspection Checklist Legend

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%)**
			

ELM DRIVE, CITY OF MISSISSAUGA

LOW IMPACT DEVELOPMENT INFRASTRUCTURE PERFORMANCE AND RISK MANAGEMENT ASSESSMENT

Appendix F

Bioretention Cell Soil and Infiltration Tests

1 INFILTRATION ANALYSIS

The LID infrastructure at Elm Drive is designed to reduce runoff by allowing water to infiltrate through permeable pavement and filter media. Filter media (soil) in the bioretention cells has been engineered to remove pollutants for stormwater through chemical, biological and physical processes. It is important that the filter media and permeable pavement function properly to ensure effective stormwater management.

1.1 Filter Media

A Guelph Permeameter was used to measure the infiltration rate of the bioretention cell filter media. Constant head permeability testing with the Guelph Permeameter was conducted on unsaturated filter media. The tests were conducted until steady state flow (saturated hydraulic conductivity) was achieved. Detailed steps for field tests and analysis were completed by following the Guelph Permeameter Operating Instructions provided by Soilmoisture Equipment Corp. The facility passes infiltration testing when the in-situ infiltration rates are higher than the minimum threshold of 25 mm/hr. Filter media infiltration tests at were performed on October 17, 2013. Two tests were performed in cell 6 and cell 4 (four tests in total).

1.2 Permeable Pavement

The infiltration rate of the permeable pavement sections (lay-bys and sidewalk) were established by following ASTM C1701. A single ring infiltrometer (300 mm diameter) was temporarily affixed to the permeable pavement with putty to create a water tight seal, preventing leakage. A known mass of water was poured into the infiltration ring while maintaining constant head. The elapsed time until there was no standing water on the permeable pavement surface was recorded. Determining the infiltration rate consists of two tests, a prewetting test and the actual infiltration test. A test was considered to fail if the prewetting test time exceeded 0.5 hr for 3.6 kg of water to infiltrate (approximately 100 mm/hr). Permeable pavement infiltration tests at were performed on November 14, 2013. Five and seven tests were performed on the laybys and sidewalk, respectively.

1.3 Results

The infiltration results for all surface types are summarized in **Table 1-1**. Infiltration tests confirmed that the bioretention soil mix is performing at the proper infiltration rate. At this time, no soil alterations are recommended. Similarly, sidewalk permeable pavement had an infiltration rate well above the specified threshold. A couple test locations in the layby area showed poor drainage; however on average it surpassed the threshold. One of the five layby infiltration tests “failed” the prewetting test, therefore the actual infiltration test was not performed and it was not included when calculating the average infiltration rate

Table 1-1: Infiltration Testing Summary

Material	Threshold (mm/hr)	Average Rate (mm/hr)	Range (mm/hr)	Sample Number
Bioretention Filter Media	> 25	133	125 – 140	4
Permeable Pavement – Lay-bys		665	80 – 1113	4
Permeable Pavement – Sidewalk		4203	1055 – 7868	7

2 SOIL ANALYSIS

Table 2-1: Bioretention inorganics soil sampling results, 2013-2014

Parameter	Units	Detection Limit	CCME Guideline (Residential/Parkland)	EPA Guideline (Shallow Soil, Not Potable, Residential/Parkland/Institutional, Coarse Texture)	2013 Cell 1 Shallow	2013 Cell 1 Deep	2013 Cell 4 Shallow	2013 Cell 4 Deep	2013 Cell 6 Shallow	2013 Cell 6 Deep	2014 Cell 1 Shallow	2014 Cell 1 Deep	2014 Cell 4 Shallow	2014 Cell 4 Deep	2014 Cell 6 Shallow	2014 Cell 6 Deep
Total Ammonia-N	ug/g	25	*	*	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25
Soluble (20:1) Chloride (Cl)	ug/g	20	*	*	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20
Conductivity	umho/cm	1	*	700	80	85	92	72	127	115	90	93	96	81	136	113
Orthophosphate (P)	ug/g	0.2	*	*	1.5	1.4	1.5	0.9	4.4	2	1.6	0.6	1.3	0.4	5	1.2
Available (CaCl2) pH	pH	N/A	*	*	7.57	7.53	7.49	7.69	7.3	7.52	7.41	7.7	7.33	7.58	7.14	7.56
Total Kjeldahl Nitrogen	ug/g	10	*	*	380	351	346	231	594	415	316	165	665	127	771	362
Nitrite (N)	ug/g	0.5	*	*	<0.5	<0.5	<0.5	<0.5	<0.5	<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	<2	<2	<2	<2	<2	<2
Nitrate + Nitrite	ug/g	3	*	*	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3

Table 2-2: Bioretention metals soil sampling results, 2013-2014

Parameter	Units	Detection Limit	CCME Guideline (Residential/Parkland)	EPA Guideline (Shallow Soil, Not Potable, Residential/Parkland/Institutional, Coarse Texture)	2013 Cell 1 Shallow	2013 Cell 1 Deep	2013 Cell 4 Shallow	2013 Cell 4 Deep	2013 Cell 6 Shallow	2013 Cell 6 Deep	2014 Cell 1 Shallow	2014 Cell 1 Deep	2014 Cell 4 Shallow	2014 Cell 4 Deep	2014 Cell 6 Shallow	2014 Cell 6 Deep
Acid Extractable Aluminum (Al)	ug/g	50	*	*	1800	1800	1800	1800	2400	1700	1900	2100	2200	2000	2000	2200
Acid Extractable Barium (Ba)	ug/g	2	500	390	14	13	17	14	21	14	14	14	17	14	15	15
Acid Extractable Beryllium (Be)	ug/g	0.5	4	4	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<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	0.55	0.82	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50
Acid Extractable Calcium (Ca)	ug/g	500	*	*	95000	97000	96000	120000	85000	92000	94000	120000	91000	120000	87000	100000
Acid Extractable Chromium (Cr)	ug/g	1	64	160	3.2	2.9	3.3	4.7	4.6	2.9	4.2	5.1	5.5	5.9	4.5	4.8
Acid Extractable Cobalt (Co)	ug/g	2	50	22	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0
Acid Extractable Copper (Cu)	ug/g	2	63	140	6.8	8.6	7.4	7.4	11	6.7	6.6	7.8	8.7	7.6	6.7	8.9
Acid Extractable Iron (Fe)	ug/g	50	*	*	4700	4600	4600	5100	6600	4400	4900	6600	5800	6700	5400	5700
Acid Extractable Lead (Pb)	ug/g	5	140	120	<5.0	5.8	5.6	9.7	<5.0	6.6	<5.0	11	<5.0	6.6	<5.0	<5.0
Acid Extractable Magnesium (Mg)	ug/g	50	*	*	6900	13000	10000	33000	7800	8800	12000	44000	6200	43000	7500	15000
Acid Extractable Manganese (Mn)	ug/g	1	*	*	230	220	250	270	290	220	220	270	270	270	220	250
Acid Extractable Molybdenum (Mo)	ug/g	2	10	6.9	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0
Acid Extractable Nickel (Ni)	ug/g	5	50	100	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0
Acid Extractable Phosphorus (P)	ug/g	20	*	*	300	300	280	360	420	300	300	330	340	350	320	320
Acid Extractable Potassium (K)	ug/g	200	*	*	330	300	370	350	460	360	340	430	420	420	420	470
Acid Extractable Silver (Ag)	ug/g	1	20	20	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Acid Extractable Sodium (Na)	ug/g	100	*	*	<100	<100	<100	110	<100	<100	<100	130	<100	120	<100	120

Acid Extractable Strontium (Sr)	ug/g	1	*	*	120	120	120	100	110	110	120	100	120	99	120	130
Acid Extractable Sulphur (S)	ug/g	50	*	*	120	120	160	180	200	130	140	150	190	160	180	150
Acid Extractable Tin (Sn)	ug/g	20	50	*	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20
Acid Extractable Vanadium (V)	ug/g	5	130	86	7.3	7.3	7.1	8.7	9.6	6.6	7.8	12	8.6	12	8	9
Acid Extractable Zinc (Zn)	ug/g	5	200	340	12	16	15	39	20	15	17	39	18	34	15	19

Table 2-3: Bioretention PAH soil sampling results, 2013-2014

Parameter	Units	Detection Limit	CCME Guideline (Residential/Parkland)	EPA Guideline (Shallow Soil, Not Potable, Residential/Parkland/Institutional, Coarse Texture)	2013 Cell 1 Shallow	2013 Cell 1 Deep	2013 Cell 4 Shallow	2013 Cell 4 Deep	2013 Cell 6 Shallow	2013 Cell 6 Deep	2014 Cell 1 Shallow	2014 Cell 1 Deep	2014 Cell 4 Shallow	2014 Cell 4 Deep	2014 Cell 6 Shallow	2014 Cell 6 Deep
Acenaphthene	ug/g	0.005	*	7.9	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<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	<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	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050
Benzo(a)anthracene	ug/g	0.005	*	0.5	0.0056	0.005	<0.0050	<0.0050	<0.0050	<0.0050	0.037	<0.0050	0.0071	<0.0050	<0.0050	<0.0050
Benzo(a)pyrene	ug/g	0.005	0.7	0.3	0.01	0.0085	0.0078	<0.0050	<0.0050	0.0083	0.052	<0.0050	0.011	<0.0050	0.0058	<0.0050
Benzo(b/j)fluoranthene	ug/g	0.005	*	0.78	0.02	0.017	0.018	<0.0050	0.0098	0.016	0.081	<0.0050	0.023	<0.0050	0.012	0.0065
Benzo(g,h,i)perylene	ug/g	0.005	*	6.6	0.011	0.0085	0.0097	<0.0050	0.0067	0.0088	0.051	<0.0050	0.016	<0.0050	0.0089	<0.0050
Benzo(k)fluoranthene	ug/g	0.005	*	0.78	0.0056	0.005	<0.0050	<0.0050	<0.0050	<0.0050	0.024	<0.0050	0.0057	<0.0050	<0.0050	<0.0050
Chrysene	ug/g	0.005	*	7	0.0081	0.0075	0.0068	<0.0050	<0.0050	0.006	0.05	<0.0050	0.012	<0.0050	0.0053	<0.0050
Dibenz(a,h)anthracene	ug/g	0.005	*	0.1	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	0.0081	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050
Fluoranthene	ug/g	0.005	*	0.69	0.0071	0.01	0.0078	<0.0050	<0.0050	0.007	0.057	<0.0050	0.021	<0.0050	0.0068	<0.0050
Fluorene	ug/g	0.005	*	62	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050
Indeno(1,2,3-cd)pyrene	ug/g	0.005	*	0.38	0.01	0.0075	0.0087	<0.0050	0.0057	0.0079	0.046	<0.0050	0.012	<0.0050	0.0068	<0.0050
1-Methylnaphthalene	ug/g	0.005	*	0.99	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<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	<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	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050
Phenanthrene	ug/g	0.005	*	6.2	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	0.012	<0.0050	0.0076	<0.0050	<0.0050	<0.0050
Pyrene	ug/g	0.005	*	78	0.0066	0.0095	0.0063	<0.0050	<0.0050	0.007	0.046	<0.0050	0.017	<0.0050	0.0058	<0.0050

Trow

Geotechnical Investigation for Elm Drive West Reconstruction City of Mississauga

Prepared for:

Mr. Dave Morris
City of Mississauga
Transportation and Works Department
3185 Mavis Road
Mississauga, Ontario
L5C 1T7

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brge00305522a32
June 2nd, 2010

Table of Contents

Appendices

1. Introduction

This report presents the results of a geotechnical investigation carried out by Trow Associates Inc. (Trow) for the Elm Drive West Reconstruction in the City of Mississauga, Ontario. The work, authorized by Mr. Dave Morris of the City of Mississauga, was carried out in accordance with Section C, Clause 10.0 under the Procurement Agreement FA.49.292-08, Contract Number: 4600011274 – Geotechnical Engineering Field and Laboratory Testing between Trow and the City.

It is Trow's understanding that the City of Mississauga intends to reconstruct this road section by super-elevating the roadway, so that the surface storm water will flow from north towards the south. In addition, pervious parking lay-bys with bioretention swales will be constructed to allow the elimination of a standard storm water sewer for this road section.

The purpose of this geotechnical investigation is to determine the pavement layer thicknesses for the identified road section. Based on our findings, a factual geotechnical report including the layer thicknesses, soil classification and ground water condition is prepared. Percolation rate was determined based on our in-situ test data. Pavement design recommendations are not required for this project.

The scope of work included carrying out geotechnical investigation by drilling eight (8) boreholes, to determine the pavement layer thicknesses and evaluate the subsurface soil conditions at the section identified by the City of Mississauga. In addition, two (2) in-situ percolation tests were conducted to determine the percolation rate of the subgrade soil at the existing grass boulevard area.

2. Test Locations

The subject site is a 350m section of Elm Drive West located between Kariya Drive to Joan Drive in the City of Mississauga. Elm Drive is a north-south roadway with a single lane in each direction. The existing roadway consists of flexible pavement with granular covered shoulder on the north side. The area to the south side of the existing asphalt pavement is generally grass boulevard. Boreholes 1 to 4 were drilled on the asphalt pavement, approximately 75 m apart staggered on both side of the roadway where applicable. Boreholes 5 and 6 were located on the grass boulevard. An additional Borehole was drilled adjacent to each of Borehole 5 and 6 for percolation testing. The approximate boreholes locations are illustrated in Drawing No.1 attached in Appendix A of this report.

3. Geotechnical Borehole Program

On May 21, 2010, a borehole investigation program was carried out for the subject road sections. Prior to the onset of the field investigation, the borehole locations were established in the field by Trow's personnel with an approximately spacing of 75 m apart. The Boreholes were staggered in both traffic directions and were generally located at the centre of the traffic lanes.

Prior to the drilling operation, Ontario One Call and the respective utility companies were informed and clearances on the underground services/utilities in the vicinity of the borehole locations were obtained.

A total of eight (8) boreholes were advanced to approximately 1.5 to 3.0 m below the existing pavement surface to investigate the thicknesses of the various pavement layers and subgrade conditions. Groundwater conditions were observed in the open boreholes throughout the duration of drilling operation at each borehole. Samples of granular base/subbase materials were collected from the field and are available at Trow for any future testing, if required.

The drilling equipment used to advance the boreholes consisted of a power auger drill-rig mounted on a rubber-tire truck unit. The borehole were advanced to the desired depths using continuous flight, solid stem augers, under fulltime supervision of a Trow field engineer.

The approximate borehole locations are shown in Drawings No. 1 in Appendix A of this report. Drawing No. 2 through 7 in Appendix B contains the detailed borehole logs.

4. Findings of the Geotechnical Borehole Program

4.1 Elm Drive West – Existing Right of Way (Kariya Drive to Joan Drive)

A total of four (4) boreholes were drilled on the pavement section of Elm Drive West. The boreholes were drilled to a maximum depth of 2.0 m, to determine the existing asphalt and granular base/sub-base thicknesses and the subgrade conditions.

Asphalt

The existing pavement surface is composed of multiple asphalt layers. The asphalt thickness ranged from approximately 105 mm to 160 mm with an average thickness of about 124 mm.

Fill

A granular base/subbase layer, comprising mainly sand and gravel and crusher run limestone was encountered below the asphalt layer at the boreholes locations 1 to 4. The total granular base/subbase thickness ranged from approximately 100 mm to 435 mm with an average of about 239 mm.

The subgrade material encountered below the pavement structure was predominantly clayey silt fill with a trace of rootlets and gravel in dark brown to greyish black color. The measured moisture content of the clayey silt fill ranged from 13.7 to 21.4 percent. The clayey silt fill has a unit weight ranging from 19.6 to 20.7 kN/m^3.

Silt

A silt deposit was encountered at the Boreholes 1 to 4 underneath the granular and clayey silt fill layer. This material contains a trace of gravel and sand. The recorded "N" value of 25 to 68 indicates that the silt is in a compact to very dense state. The silt stratum was found at a depth of about 1.5 m below the existing grade. The measured moisture content of the silt ranged from 9.1 to 13.9 percent. The silt has a unit weights of 20.8 to 22.2 kN/m^3.

4.1.1 Ground water Condition

Groundwater was not encountered in any of the boreholes advanced.

4.2 Elm Drive West – Existing Grass Boulevard

Two (2) boreholes (Boreholes 5 and 6) were drilled on the grass boulevard on the south side of the subjected section of Elm Drive West to determine the existing subsurface conditions.

An additional borehole was drilled adjacent to each of Boreholes 5 and 6 for percolation testing.

Topsoil

At Boreholes 5 and 6, a topsoil layer of approximately 75 and 360 mm in thickness was encountered at surface, respectively. The determined moisture content of the topsoil was about 34.2 percent.

Fill

A clayey silt fill layer with a thickness of about 1 to 1.5 m was encountered below the topsoil layer at Boreholes 5 and 6. The recorded "N" value of 6 to 10 blows indicates that the fill is in a loose state. The moisture content of the clayey silt layer material was measured at approximately 15.2 to 25.5 percent. The measured unit weight of the fill is 19.5 to 20.7 kN/m^3

Silt Till

A silt till deposit was encountered below the clayey silt fill at Boreholes 5 and 6. This material contains a trace of gravel, highly weathered shale fragments and limestone layers. The recorded "N" value of 78 blows per 300 mm and 30 blows per 150 mm penetration indicates that the silt till is in a very dense state. The silt till was found at a depth of about 1.5m below the existing grade. The silt till has a moisture content vary from about 5.4 to 16.8 percent and unit weight of about 21.2 to 21.7 kN/m^3.

4.2.1 Ground water Condition

Groundwater was not encountered in any of the boreholes advanced.

4.3 Percolation Tests

Two percolation tests were conducted at the site, adjacent to Boreholes 5 and 6 at locations shown in the attached Drawing 1 of Appendix A of this report.

At both locations, an additional borehole was drilled to approximately 1.1 meter depth into the clayey silt layer. A layer of clear stone of about 0.1m in thickness was placed at the bottom of each borehole. The boreholes were then filled with water to about 0.3 m below the ground surface. The soil was allowed to saturate for 4 hours before the actual percolation measurements were made.

Over the 4 hours saturation period, the water level in Borehole 5 dropped by approximately 30mm while in Borehole 6, there was no change in water level. Three additional readings were conducted after the saturation, no additional water level drop was measured in both boreholes.

Stable rate was reached after the saturation period while the drop in two successive readings does not vary by more than 1.5mm. The computed time (T) is practically equal to zero based on the Average drop of the last 3 readings. The relationship between the water level drop versus time in minutes is illustrated in Figure 1 of Appendix B attached to this report.

5. Closure

The City of Mississauga retained Trow Associates Inc. to undertake geotechnical evaluation of the Elm Drive West road section under its domain that is earmarked for reconstruction during the 2010 construction season.

A detailed geotechnical investigation plan consisting of drilling auger-holes at approximately 75 m, staggered on all traveled lanes and directions to estimate the appropriate layer thicknesses and subgrade condition.

The information presented in this report is based on a limited investigation designed to provide information for an overall assessment of the current geotechnical conditions of the subject site. The information presented in this report reflects the existing site conditions at the time of the investigation.

The comments given in this report are intended only for the guidance of design engineers. The number of boreholes required to determine the localized underground conditions between boreholes affecting construction costs, techniques, sequencing, equipment, scheduling, etc., would be much greater than has been carried out for design purposes. Contractors bidding on or undertaking the works should, in this light, decide on their own investigations, as well as their own interpretations of the factual borehole results, so that they may draw their own conclusions as to how the subsurface conditions may affect them.

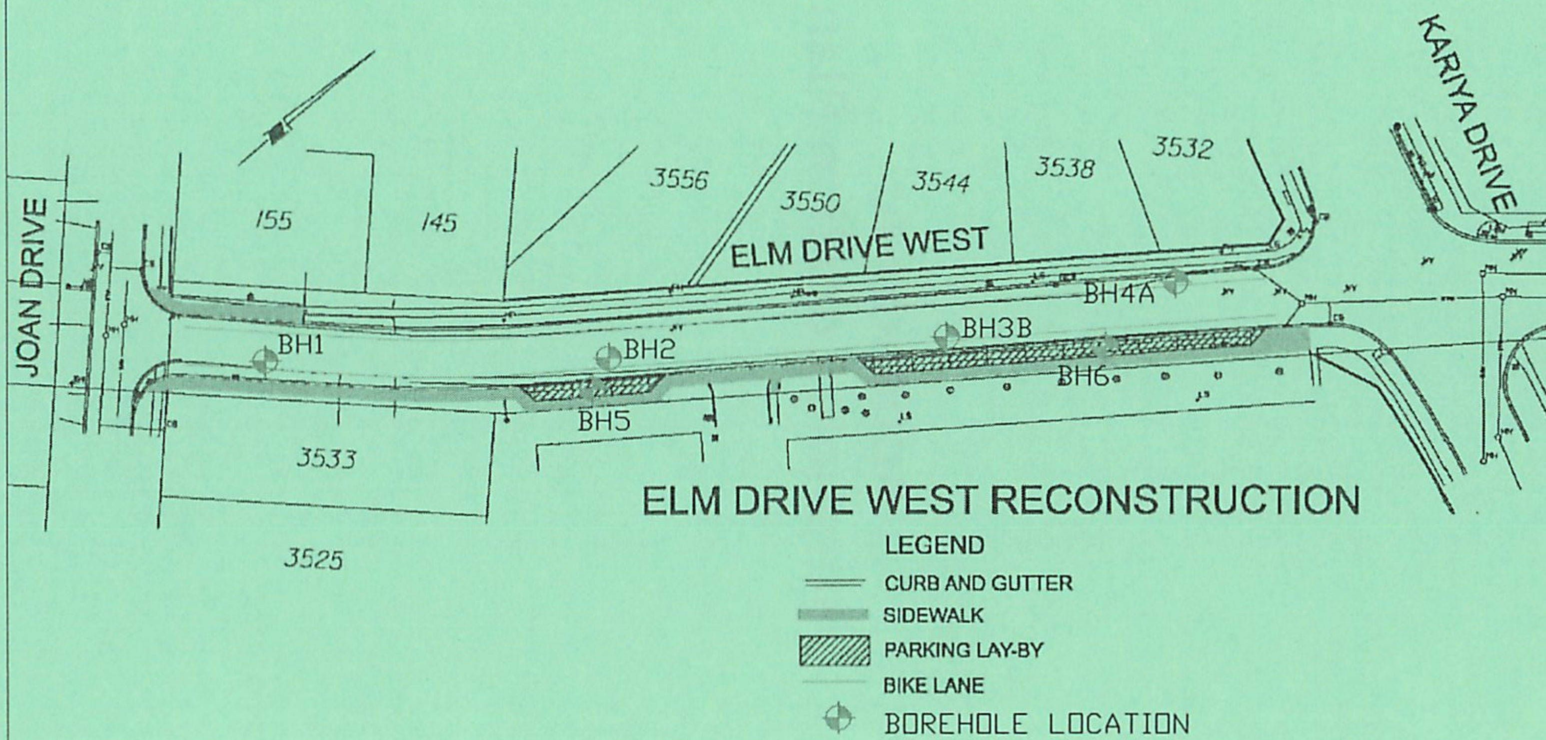
More specific information, with respect to the conditions between samples, or the lateral and vertical extent of materials, may become apparent during excavation operations. Consequently, during the future construction works, conditions not observed during this investigation may become apparent; should this occur, Trow Associates Inc. should be contacted to assess the situation, and additional testing and reporting may be required. Trow has qualified personnel to provide assistance in regards to future geotechnical and environmental issues related to these projects.

We hope this submission is satisfactory for your purposes, and should there be any questions, please don't hesitate to contact the undersigned.

Trow Associates Inc.

Eric Chan, P.Eng. Pavement and Materials Engineer Trow Associates Inc.	Kevin W.Y. Leung, M.Sc., P.Eng. Senior Engineer Trow Associates Inc.

Appendix A:
Borehole Location Plan



Trow Associates Inc. 1595 CLARK BOULEVARD BRAMPTON, ONTARIO, L6T 4V1 (905) 793-9800	ELM DRIVE WEST RECONSTRUCTION CITY OF MISSISSAUGA, ONTARIO	BOREHOLE PLAN	BRGE00305522A32	EC
			NTS	MG
			MAY 2010	1

Appendix B:
Borehole Logs and Percolation Graph

Log of Borehole 1

Project No. brge00305522a32 Drawing No. 2

Project: Geotechnical Investigation for Elm Drive West Reconstruction Sheet No. 1 of 1

Location: from (Joan Drive to Kariya Drive)

Existing Right of Way

Date Drilled: May 21, 2010

Drill Type: CME 45 -Truck Mount

Datum: Geodetic-Bench Mark Number 366

Auger Sample; SPT (N) Value; Dynamic Cone Test; Shelby Tube; Field Vane Test

Combustible Vapour Reading; Natural Moisture; Plastic and Liquid Limit; Undrained Triaxial at % Strain at Failure; Penetrometer

GWL	SYMBOL	Soil Description	ELEV. m	DEPTH	N Value 20 40 60 80 / Shear Strength 100 200 kPa	Combustible Vapour Reading (ppm) 25 50 75 / Natural Moisture Content % Atterberg Limits (% Dry Weight) 10 20 30	SAMPLES	Natural Unit Weight kN/m³
			149.93	0				
		ASPHALT~160 mm over	149.8					
		FILL - 100 mm crusher run limestone, grey, moist	149.7					
		Clayey Silt - black to dark grey, trace gravel, moist - occasional grinding	148.4	1	10			
		SILT TILL - brown, moist, light grey, hard	148.0		68/ 280mm			22.2
		END OF BOREHOLE						

LAGWGL02 BOREHOLE LOGS BRGE00305522A32.GPJ NEW.GDT 6/2/10

Trow

Time	Water Level (m)	Depth to Cave (m)
On Completion	No free water	Nil

Log of Borehole 2

Project No. brge00305522a32 — Drawing No. 3

Project: Geotechnical Investigation for Elm Drive West Reconstruction — Sheet No. 1 of 1

Location: from (Joan Drive to Kariya Drive)

Existing Right of Way

Date Drilled: May 21, 2010

Drill Type: CME 45 -Truck Mount

Datum: Geodetic-Bench Mark Number 366

Symbol	Legend	Symbol	Legend
☒	Auger Sample	□	Combustible Vapour Reading
○ ⧄	SPT (N) Value	✕	Natural Moisture
─	Dynamic Cone Test	├──○	Plastic and Liquid Limit
■	Shelby Tube	⊕	Undrained Triaxial at % Strain at Failure
✚ S	Field Vane Test	▲	Penetrometer

GWL	Soil Description	ELEV. m	DEPTH	N Value / Shear Strength (kPa)	Combustible Vapour Reading (ppm) / Natural Moisture Content % / Atterberg Limits (% Dry Weight)	SAMPLES	Natural Unit Weight kN/m³
		149.52	0				
	ASPHALT~105 mm over	149.4					
	FILL - 245 mm crusher run limestone over sand and gravel layer, grey to brown, moist	149.2				Auger	
	Clayey Silt - black to dark grey, trace gravel, moist			N = 9		Auger; SPT	19.6
			1				
		148.0					
	SILT TILL - grey, trace of limestone pieces, moist, hard			N = 34; Penetrometer >		SPT	20.8
		147.5					
	END OF BOREHOLE						

Scale headings: N Value 20, 40, 60, 80; Shear Strength 100, 200 kPa; Combustible Vapour Reading 25, 50, 75; Natural Moisture Content 10, 20, 30.

LAGWGL02 BOREHOLE LOGS BRGE00305522A32.GPJ NEW.GDT 6/2/10

Time	Water Level (m)	Depth to Cave (m)
On Completion	No free water	Nil

Trow

Log of Borehole 3

Project No. brge00305522a32 — Drawing No. 4

Project: Geotechnical Investigation for Elm Drive West Reconstruction — Sheet No. 1 of 1

Location: from (Joan Drive to Kariya Drive)

Existing Right of Way

Date Drilled: May 21, 2010

Drill Type: CME 45 -Truck Mount

Datum: Geodetic-Bench Mark Number 366

Legend	Symbol
Auger Sample	⊠
SPT (N) Value	○ ▨
Dynamic Cone Test	——
Shelby Tube	■
Field Vane Test	✚ S
Combustible Vapour Reading	□
Natural Moisture	×
Plastic and Liquid Limit	├──○
Undrained Triaxial at % Strain at Failure	⊕
Penetrometer	▲

GWL	Symbol	Soil Description	ELEV. m	Depth (m)	N Value / Shear Strength (kPa)	Natural Moisture Content %	Samples	Natural Unit Weight kN/m³
			148.15	0				
		ASPHALT~115 mm over	148.0					
		FILL - 195 mm mix of crusher run limestone with sand and gravel, brown, moist	147.8			×	Auger	
		Clayey Silt - dark grey mottled with black, trace gravel, moist				×	Auger	
					○ 9	×	SPT	20.5
			146.6	1				
		SILT TILL - light grey to brown, trace of limestone pieces, moist, very stiff			○ 26; ▲ >	×	SPT	21.4
			146.2					
		END OF BOREHOLE						

Time	Water Level (m)	Depth to Cave (m)
On Completion	No free water	Nil

Trow

Log of Borehole 4

Project No. brge00305522a32 | Drawing No. 5

Project: Geotechnical Investigation for Elm Drive West Reconstruction | Sheet No. 1 of 1

Location: from (Joan Drive to Kariya Drive)

Existing Right of Way

Date Drilled: May 21, 2010

Drill Type: CME 45 - Track Mount

Datum: Geodetic-Bench Mark Number 366

Auger Sample ⊠
SPT (N) Value ○ ◪
Dynamic Cone Test —
Shelby Tube ■
Field Vane Test ✚S

Combustible Vapour Reading □
Natural Moisture ×
Plastic and Liquid Limit ⊢—○
Undrained Triaxial at % Strain at Failure ⊕
Penetrometer ▲

GWL	Symbol	Soil Description	ELEV. m	Depth	N Value (20, 40, 60, 80) / Shear Strength kPa (100, 200)	Combustible Vapour Reading (ppm) (25, 50, 75) / Natural Moisture Content % / Atterberg Limits (% Dry Weight) (10, 20, 30)	Samples	Natural Unit Weight kN/m³
		ASPHALT~115 mm over	146.85	0				
		FILL - 80 mm of crusher run limestone over 360mm of sand and gravel, brown, moist	146.7			×	⊠	
		Clayey Silt - dark grey mottled with black, trace gravel, wood, rootlets, moist	146.3	1	○ 7	×	⊠ ◪	20.3
		SILT TILL - light grey to brown, trace of highly weathered shale and limestone pieces, moist, hard	145.2		○ 45 ▲ >	×	◪	19.3
		END OF BOREHOLE	144.9					

LAGW3L02 BOREHOLE LOGS BRGE00305522A32.GPJ NEW.GDT 6/2/10

Trow

Time	Water Level (m)	Depth to Cave (m)
On Completion	No free water	Nil

Log of Borehole 5

Project No. brge00305522a32 — Drawing No. 6

Project: Geotechnical Investigation for Elm Drive West Reconstruction — Sheet No. 1 of 1

Location: from (Joan Drive to Kariya Drive)

Existing Grass Blvd.

Date Drilled: May 21, 2010

Drill Type: CME 45 - Track Mount

Datum: Geodetic-Bench Mark Number 366

Legend	
Auger Sample	⊠
SPT (N) Value	O ▨
Dynamic Cone Test	—
Shelby Tube	■
Field Vane Test	✚ S
Combustible Vapour Reading	□
Natural Moisture	×
Plastic and Liquid Limit	├──○
Undrained Triaxial at % Strain at Failure	⊕
Penetrometer	▲

GWL	Symbol	Soil Description	ELEV. m	Depth (m)	N Value / Shear Strength (kPa)	Natural Moisture Content %	Samples	Natural Unit Weight kN/m³
			149.04	0				
		TOPSOIL - 80mm, dark brown, moist	149.0					
		CLAYEY SILT - brown, trace of gravel, rootlets, moist			11	×	▨	20.7
				1	73/ 280mm; > ▲	×	▨	21.9
		- occasional grinding						
		SILT TILL - grey, some highly weathered shale fragments layers and limestone pieces, hard - occasional hard grinding	147.5		78; > ▲	×	▨	21.2
				2				
					90/ 230mm	×	▨	
		END OF BOREHOLE	146.5					

Time	Water Level (m)	Depth to Cave (m)
On Completion	No free water	Nil

Trow

LAGWGL02 BOREHOLE LOGS BRGE00305522A32.GPJ NEW.GDT 6/2/10

Log of Borehole 6

Project No.	brge00305522a32	Drawing No.	7
Project:	Geotechnical Investigation for Elm Drive West Reconstruction	Sheet No.	1 of 1
Location:	from (Joan Drive to Kariya Drive)		
	Existing Grass Blvd.		
Date Drilled:	May 21, 2010		
Drill Type:	CME 45 - Track Mount		
Datum:	Geodetic-Bench Mark Number 366		

Auger Sample ⊠
SPT (N) Value ○ ▨
Dynamic Cone Test —
Shelby Tube ■
Field Vane Test ✚S

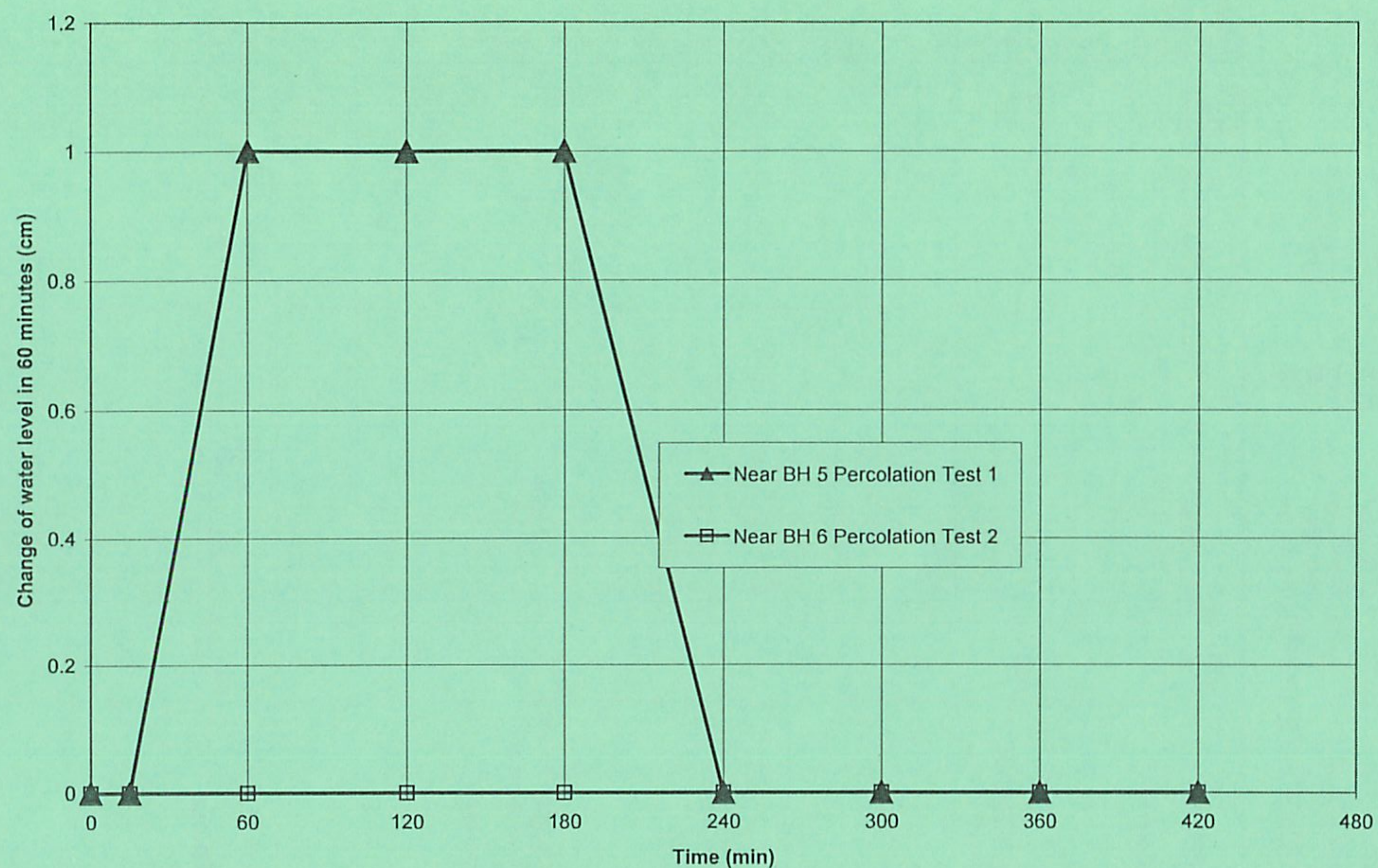
Combustible Vapour Reading □
Natural Moisture ×
Plastic and Liquid Limit ├──○
Undrained Triaxial at % Strain at Failure ⊕
Penetrometer ▲

GWL	Symbol	Soil Description	ELEV. m	Depth	N Value (20 40 60 80) / Shear Strength kPa (100 200)	Combustible Vapour Reading (ppm) (25 50 75) / Natural Moisture Content % / Atterberg Limits (% Dry Weight) (10 20 30)	Samples	Natural Unit Weight kN/m^3
		TOPSOIL - 360 mm, dark brown, moist	146.71	0				
					5	×		
		CLAYEY SILT - brown mottled with grey, trace of gravel, rootlets, moist	146.4					
				1	6	×		19.5
		SILT TILL - grey, some highly weathered shale fragments layers and limestone pieces, hard - very hard grinding occasionaly	145.2		30/ 130mm; > ▲	×		
				2				
			144.3		50/ 100mm; > ▲	×		21.7
		END OF BOREHOLE						

LAGWGL02 BOREHOLE LOGS BRGE00305522A32.GPJ NEW.GDT 6/2/10

Time	Water Level (m)	Depth to Cave (m)
On Completion	No free water	Nil

Trow



Trow

Trow Associates Inc.

PERCOLATION TEST RESULTS

Elm Drive West, Mississauga, Ontario

FIGURE No.	1
REF. No.	BRGE00305522a32
DATE	MAY 2010

Your Project #: PUBLIC LANDS
Your C.O.C. #: NA

Attention: Andrew O'Rourke
Credit Valley Conservation
1255 Old Derry Rd
Meadowvale
Mississauga, ON
L5N 6R4

Report Date: 2012/07/13

CERTIFICATE OF ANALYSIS

MAXXAM JOB #: B297842
Received: 2012/06/29, 13:28

Sample Matrix: Soil
Samples Received: 28

Analyses	Quantity	Date Extracted	Date Analyzed	Laboratory Method	Method Reference
Chloride (20:1 extract)	28	N/A	2012/07/09	CAM SOP-00463	EPA 325.2
pH CaCl2 EXTRACT	3	2012/07/05	2012/07/05	CAM SOP-00413	SM 4500H+ B
pH CaCl2 EXTRACT	25	2012/07/06	2012/07/06	CAM SOP-00413	SM 4500H+ B
Orthophosphate Analysis	20	N/A	2012/07/09	CAM SOP-00461	Based on EPA 365.1
Orthophosphate Analysis	8	N/A	2012/07/10	CAM SOP-00461	Based on EPA 365.1
Sieve, 75um (1)	17	N/A	2012/07/05	CAM SOP-00467	M.R Carter SSMA
Sieve, 75um (1)	11	N/A	2012/07/06	CAM SOP-00467	M.R Carter SSMA
Total Organic Carbon in Soil	13	N/A	2012/07/05	CAM SOP-00468	LECO Combustion
Total Organic Carbon in Soil	15	N/A	2012/07/09	CAM SOP-00468	LECO Combustion

* RPDs calculated using raw data. The rounding of final results may result in the apparent difference.

(1) The Sieve test has been validated in accordance with ISO Guide 17025 requirements. SCC accreditation pending.

Encryption Key

Please direct all questions regarding this Certificate of Analysis to your Project Manager.

Christine Gripton, Project Manager
Email: CGripton@maxxam.ca
Phone# (800) 268-7396 Ext:250

==
Maxxam has procedures in place to guard against improper use of the electronic signature and have the required "signatories", as per section 5.10.2 of ISO/IEC 17025:2005(E), signing the reports. For Service Group specific validation please refer to the Validation Signature Page.

Total cover pages: 1

Maxxam Job #: B297842
Report Date: 2012/07/13

Credit Valley Conservation
Client Project #: PUBLIC LANDS

RESULTS OF ANALYSES OF SOIL

Maxxam ID		NZ2607		NZ2608	NZ2608		
Sampling Date		2012/06/21 09:30		2012/06/21 09:35	2012/06/21 09:35		
COC Number		NA		NA	NA		
	Units	**GG-S1**	**QC Batch**	**GG-S2**	**GG-S2 Lab-Dup**	**RDL**	**QC Batch**
Inorganics							
Soluble (20:1) Chloride (Cl)	ug/g	<20	2900677	<20		20	2900677
Total Organic Carbon	mg/kg	25000	2898583	23000	21000	500	2898854
Orthophosphate (P)	ug/g	10	2900673	9.0		0.2	2900673
Available (CaCl2) pH	pH	7.15	2899333	6.95			2900406
Miscellaneous Parameters							
Grain Size	%	COARSE	2899006	COARSE		N/A	2899006
Sieve - #200 (<0.075mm)	%	15	2899006	14		N/A	2899006
Sieve - #200 (>0.075mm)	%	85	2899006	86		N/A	2899006

RDL = Reportable Detection Limit
Lab-Dup = Laboratory Initiated Duplicate
QC Batch = Quality Control Batch

Maxxam ID		NZ2609	NZ2610	NZ2610		NZ2611		
Sampling Date		2012/06/21 09:49	2012/06/21 09:49	2012/06/21 09:49		2012/06/21 10:05		
COC Number		NA	NA	NA		NA		
	Units	**GG-D1**	**GG-D2**	**GG-D2 Lab-Dup**	**QC Batch**	**LS-S1**	**RDL**	**QC Batch**
Inorganics								
Soluble (20:1) Chloride (Cl)	ug/g	68	85		2900402	180	20	2900677
Total Organic Carbon	mg/kg	20000	18000		2898583	19000	500	2898854
Orthophosphate (P)	ug/g	6.5	6.1	5.5	2900407	4.1	0.2	2900673
Available (CaCl2) pH	pH	7.06	7.14		2900360	7.12		2900406
Miscellaneous Parameters								
Grain Size	%	COARSE	COARSE		2899006	COARSE	N/A	2899006
Sieve - #200 (<0.075mm)	%	24	22		2899006	33	N/A	2899006
Sieve - #200 (>0.075mm)	%	76	78		2899006	67	N/A	2899006

RDL = Reportable Detection Limit
Lab-Dup = Laboratory Initiated Duplicate
QC Batch = Quality Control Batch

Maxxam Job #: B297842
Report Date: 2012/07/13

Credit Valley Conservation
Client Project #: PUBLIC LANDS

RESULTS OF ANALYSES OF SOIL

Maxxam ID		NZ2612		NZ2613	NZ2614		
Sampling Date		2012/06/21 10:05		2012/06/21 10:10	2012/06/21 10:10		
COC Number		NA		NA	NA		
	Units	**LS-S2**	**QC Batch**	**LS-D1**	**LS-D2**	**RDL**	**QC Batch**
Inorganics							
Soluble (20:1) Chloride (Cl)	ug/g	170	2900402	120	130	20	2900677
Total Organic Carbon	mg/kg	17000	2898583	15000	15000	500	2898854
Orthophosphate (P)	ug/g	3.7	2900407	5.1	5.1	0.2	2900673
Available (CaCl2) pH	pH	7.15	2900406	7.10	7.11		2900406
Miscellaneous Parameters							
Grain Size	%	COARSE	2899006	COARSE	COARSE	N/A	2899006
Sieve - #200 (<0.075mm)	%	35	2899006	35	37	N/A	2899006
Sieve - #200 (>0.075mm)	%	65	2899006	65	63	N/A	2899006

RDL = Reportable Detection Limit
QC Batch = Quality Control Batch

Maxxam ID		NZ2615		NZ2616		NZ2617		
Sampling Date		2012/06/21 11:30		2012/06/21 11:30		2012/06/21 11:35		
COC Number		NA		NA		NA		
	Units	**ED-S1**	**QC Batch**	**ED-S2**	**QC Batch**	**ED-D1**	**RDL**	**QC Batch**
Inorganics								
Soluble (20:1) Chloride (Cl)	ug/g	<20	2900677	<20	2900677	<20	20	2900677
Total Organic Carbon	mg/kg	7200	2898854	7200	2898583	7200	500	2898854
Orthophosphate (P)	ug/g	2.0	2900673	1.9	2900673	1.8	0.2	2900673
Available (CaCl2) pH	pH	7.64	2899333	7.58	2900406	7.45		2900360
Miscellaneous Parameters								
Grain Size	%	COARSE	2899006	COARSE	2899006	COARSE	N/A	2899006
Sieve - #200 (<0.075mm)	%	10	2899006	12	2899006	14	N/A	2899006
Sieve - #200 (>0.075mm)	%	90	2899006	88	2899006	86	N/A	2899006

RDL = Reportable Detection Limit
QC Batch = Quality Control Batch

Maxxam Job #: B297842
Report Date: 2012/07/13

Credit Valley Conservation
Client Project #: PUBLIC LANDS

RESULTS OF ANALYSES OF SOIL

Maxxam ID		NZ2617	NZ2618	NZ2619		NZ2620		
Sampling Date		2012/06/21 11:35	2012/06/21 11:35	2012/06/21 13:10		2012/06/21 13:10		
COC Number		NA	NA	NA		NA		
	Units	**ED-D1 Lab-Dup**	**ED-D2**	**UC-S1**	**QC Batch**	**UC-S2**	**RDL**	**QC Batch**
Inorganics								
Soluble (20:1) Chloride (Cl)	ug/g		<20	99	2900677	95	20	2900677
Total Organic Carbon	mg/kg		6800	5100	2898854	5200	500	2898583
Orthophosphate (P)	ug/g	1.8	1.6	6.0	2900673	7.1	0.2	2900673
Available (CaCl2) pH	pH		7.47	7.10	2900360	7.09		2900360
Miscellaneous Parameters								
Grain Size	%		COARSE	COARSE	2899006	COARSE	N/A	2899006
Sieve - #200 (<0.075mm)	%		12	44	2899006	43	N/A	2899006
Sieve - #200 (>0.075mm)	%		88	56	2899006	57	N/A	2899006

RDL = Reportable Detection Limit
Lab-Dup = Laboratory Initiated Duplicate
QC Batch = Quality Control Batch

Maxxam ID		NZ2621			NZ2622			NZ2623		
Sampling Date		2012/06/21 13:15			2012/06/21 13:15			2012/06/21 13:45		
COC Number		NA			NA			NA		
	Units	**UC-D1**	**RDL**	**QC Batch**	**UC-D2**	**RDL**	**QC Batch**	**PC-S1**	**RDL**	**QC Batch**
Inorganics										
Soluble (20:1) Chloride (Cl)	ug/g	110	20	2900677	<100 (1)	100	2900677	44	20	2900677
Total Organic Carbon	mg/kg	7200	500	2898854	7200	500	2898583	9600	500	2898854
Orthophosphate (P)	ug/g	9.5	0.2	2900673	11 (2)	1	2900673	4.5	0.2	2900673
Available (CaCl2) pH	pH	7.15		2900360	7.05		2900406	7.15		2900406
Miscellaneous Parameters										
Grain Size	%	COARSE	N/A	2899006	COARSE	N/A	2899006	COARSE	N/A	2899006
Sieve - #200 (<0.075mm)	%	45	N/A	2899006	49	N/A	2899006	9.8	N/A	2899006
Sieve - #200 (>0.075mm)	%	55	N/A	2899006	51	N/A	2899006	90	N/A	2899006

RDL = Reportable Detection Limit
QC Batch = Quality Control Batch
(1) Due to the colour interferences, sample required dilution. Detection limit was adjusted accordingly.
(2) Due to the sample matrix, sample required dilution. Detection limit was adjusted accordingly.

RESULTS OF ANALYSES OF SOIL

Maxxam ID		NZ2624		NZ2625		NZ2626		
Sampling Date		2012/06/21 13:45		2012/06/21 13:50		2012/06/21 13:50		
COC Number		NA		NA		NA		
	Units	**PC-S2**	**QC Batch**	**PC-D1**	**QC Batch**	**PC-D2**	**RDL**	**QC Batch**
Inorganics								
Soluble (20:1) Chloride (Cl)	ug/g	55	2900402	51	2900402	51	20	2900677
Total Organic Carbon	mg/kg	12000	2898583	8600	2898583	8200	500	2898854
Orthophosphate (P)	ug/g	4.5	2900407	5.1	2900407	5.7	0.2	2900673
Available (CaCl2) pH	pH	7.10	2900360	7.11	2900406	6.94		2900519
Miscellaneous Parameters								
Grain Size	%	COARSE	2899795	COARSE	2899795	COARSE	N/A	2899795
Sieve - #200 (<0.075mm)	%	11	2899795	8.6	2899795	9.8	N/A	2899795
Sieve - #200 (>0.075mm)	%	89	2899795	91	2899795	90	N/A	2899795

RDL = Reportable Detection Limit
QC Batch = Quality Control Batch

Maxxam ID		NZ2627	NZ2627		NZ2628	NZ2629		
Sampling Date		2012/06/28 09:35	2012/06/28 09:35		2012/06/28 09:35	2012/06/28 09:45		
COC Number		NA	NA		NA	NA		
	Units	**OP-S1**	**OP-S1 Lab-Dup**	**QC Batch**	**OP-S2**	**OP-D1**	**RDL**	**QC Batch**
Inorganics								
Soluble (20:1) Chloride (Cl)	ug/g	<20	<20	2900677	<20	<20	20	2900677
Total Organic Carbon	mg/kg	15000		2898583	14000	11000	500	2898854
Orthophosphate (P)	ug/g	2.8		2900673	3.2	6.1	0.2	2900673
Available (CaCl2) pH	pH	7.13		2900360	7.06	7.21		2900360
Miscellaneous Parameters								
Grain Size	%	COARSE		2899795	COARSE	COARSE	N/A	2899795
Sieve - #200 (<0.075mm)	%	33		2899795	40	22	N/A	2899795
Sieve - #200 (>0.075mm)	%	67		2899795	60	78	N/A	2899795

RDL = Reportable Detection Limit
Lab-Dup = Laboratory Initiated Duplicate
QC Batch = Quality Control Batch

Maxxam Job #: B297842
Report Date: 2012/07/13

Credit Valley Conservation
Client Project #: PUBLIC LANDS

RESULTS OF ANALYSES OF SOIL

Maxxam ID		NZ2630			NZ2631			NZ2632		
Sampling Date		2012/06/28 09:45			2012/06/26 13:50			2012/06/26 13:50		
COC Number		NA			NA			NA		
	Units	**OP-D2**	**RDL**	**QC Batch**	**TC-S1**	**RDL**	**QC Batch**	**TC-S2**	**RDL**	**QC Batch**
Inorganics										
Soluble (20:1) Chloride (Cl)	ug/g	<20	20	2900402	<100 (1)	100	2900677	<200 (1)	200	2900402
Total Organic Carbon	mg/kg	12000	500	2898583	87000	500	2898854	57000	500	2898583
Orthophosphate (P)	ug/g	6.0	0.2	2900407	24 (2)	1	2900673	23 (2)	0.6	2900407
Available (CaCl2) pH	pH	7.28		2900360	6.83		2900360	6.95		2899333
Miscellaneous Parameters										
Grain Size	%	COARSE	N/A	2899795	FINE	N/A	2899795	FINE	N/A	2899795
Sieve - #200 (<0.075mm)	%	17	N/A	2899795	64	N/A	2899795	57	N/A	2899795
Sieve - #200 (>0.075mm)	%	83	N/A	2899795	36	N/A	2899795	43	N/A	2899795

RDL = Reportable Detection Limit
QC Batch = Quality Control Batch
(1) Due to the colour interferences, sample required dilution. Detection limit was adjusted accordingly.
(2) Due to the sample matrix, sample required dilution. Detection limit was adjusted accordingly.

Maxxam ID		NZ2633			NZ2634		
Sampling Date		2012/06/26 14:00			2012/06/26 14:00		
COC Number		NA			NA		
	Units	**TC-D1**	**RDL**	**QC Batch**	**TC-D2**	**RDL**	**QC Batch**
Inorganics							
Soluble (20:1) Chloride (Cl)	ug/g	<100 (1)	100	2900677	<200 (1)	200	2900402
Total Organic Carbon	mg/kg	83000	500	2898583	70000	500	2898854
Orthophosphate (P)	ug/g	24 (2)	1	2900673	29 (2)	0.6	2900407
Available (CaCl2) pH	pH	6.86		2900406	6.82		2900406
Miscellaneous Parameters							
Grain Size	%	FINE	N/A	2899795	FINE	N/A	2899795
Sieve - #200 (<0.075mm)	%	57	N/A	2899795	52	N/A	2899795
Sieve - #200 (>0.075mm)	%	43	N/A	2899795	48	N/A	2899795

RDL = Reportable Detection Limit
QC Batch = Quality Control Batch
(1) Due to the colour interferences, sample required dilution. Detection limit was adjusted accordingly.
(2) Due to the sample matrix, sample required dilution. Detection limit was adjusted accordingly.

Maxxam Analytics International Corporation o/a Maxxam Analytics 6740 Campobello Road, Mississauga, Ontario, L5N 2L8 Tel: (905) 817-5700 Toll-Free: 800-563-6266 Fax: (905) 817-5777 www.maxxam.ca

Package 1	24.3°C

Each temperature is the average of up to three cooler temperatures taken at receipt

GENERAL COMMENTS

Results relate only to the items tested.

Maxxam Analytics International Corporation o/a Maxxam Analytics 6740 Campobello Road, Mississauga, Ontario, L5N 2L8 Tel: (905) 817-5700 Toll-Free: 800-563-6266 Fax: (905) 817-5777 www.maxxam.ca

Credit Valley Conservation
Attention: Andrew O'Rourke
Client Project #: PUBLIC LANDS
P.O. #:
Site Location:

Quality Assurance Report

Maxxam Job Number: MB297842

QA/QC Batch Num	Init	QC Type	Parameter	Date Analyzed yyyy/mm/dd	Value	Recovery	Units	QC Limits
2898583	OK	QC Standard	Total Organic Carbon	2012/07/05		95	%	80 - 120
		Method Blank	Total Organic Carbon	2012/07/05	<500		mg/kg	
		RPD	Total Organic Carbon	2012/07/05	1.2		%	35
2898854	OK	QC Standard	Total Organic Carbon	2012/07/09		98	%	80 - 120
		Method Blank	Total Organic Carbon	2012/07/09	<500		mg/kg	
		RPD [NZ2608-01]	Total Organic Carbon	2012/07/09	6.9		%	35
2899006	THT	QC Standard	Sieve - #200 (<0.075mm)	2012/07/05		89	%	86 - 91
			Sieve - #200 (>0.075mm)	2012/07/05		11	%	9 - 14
		RPD	Sieve - #200 (<0.075mm)	2012/07/05	0.8		%	20
			Sieve - #200 (>0.075mm)	2012/07/05	3.9		%	20
2899795	THT	QC Standard	Sieve - #200 (<0.075mm)	2012/07/06		89	%	86 - 91
			Sieve - #200 (>0.075mm)	2012/07/06		11	%	9 - 14
		RPD	Sieve - #200 (<0.075mm)	2012/07/06	1.6		%	20
			Sieve - #200 (>0.075mm)	2012/07/06	2.1		%	20
2900402	DRM	Matrix Spike	Soluble (20:1) Chloride (Cl)	2012/07/09		106	%	75 - 125
		Spiked Blank	Soluble (20:1) Chloride (Cl)	2012/07/09		105	%	75 - 125
		Method Blank	Soluble (20:1) Chloride (Cl)	2012/07/09	<20		ug/g	
		RPD	Soluble (20:1) Chloride (Cl)	2012/07/09	NC		%	35
2900407	BIP	Matrix Spike [NZ2610-01]	Orthophosphate (P)	2012/07/10		110	%	75 - 125
		Spiked Blank	Orthophosphate (P)	2012/07/06		109	%	75 - 125
		Method Blank	Orthophosphate (P)	2012/07/06	<0.2		ug/g	
		RPD [NZ2610-01]	Orthophosphate (P)	2012/07/10	10.6		%	35
2900673	BIP	Matrix Spike [NZ2617-01]	Orthophosphate (P)	2012/07/09		115	%	75 - 125
		Spiked Blank	Orthophosphate (P)	2012/07/09		106	%	75 - 125
		Method Blank	Orthophosphate (P)	2012/07/09	<0.2		ug/g	
		RPD [NZ2617-01]	Orthophosphate (P)	2012/07/09	3.6		%	35
2900677	DRM	Matrix Spike [NZ2627-01]	Soluble (20:1) Chloride (Cl)	2012/07/09		105	%	75 - 125
		Spiked Blank	Soluble (20:1) Chloride (Cl)	2012/07/09		104	%	75 - 125
		Method Blank	Soluble (20:1) Chloride (Cl)	2012/07/09	<20		ug/g	
		RPD [NZ2627-01]	Soluble (20:1) Chloride (Cl)	2012/07/09	NC		%	35

Duplicate: Paired analysis of a separate portion of the same sample. Used to evaluate the variance in the measurement.
Matrix Spike: A sample to which a known amount of the analyte of interest has been added. Used to evaluate sample matrix interference.
QC Standard: A blank matrix to which a known amount of the analyte has been added. Used to evaluate analyte recovery.
Spiked Blank: A blank matrix to which a known amount of the analyte has been added. Used to evaluate analyte recovery.
Method Blank: A blank matrix containing all reagents used in the analytical procedure. Used to identify laboratory contamination.
NC (RPD): The RPD was not calculated. The level of analyte detected in the parent sample and its duplicate was not sufficiently significant to permit a reliable calculation.

Fundamental Laboratory Acceptance Guideline

Invoice To:
Credit Valley Conservation
ATTN: Phil James
1255 Old Derry Rd
Meadowvale
Mississauga, ON
L5N 6R4
Client Contact:
Andrew O'Rourke

Maxxam Job #:	B297842
Date Received:	2012/06/29
Your C.O.C. #:	NA
Your Project #:	PUBLIC LANDS
Maxxam Project Manager:	Christine Gripton
Quote #:	B23441

- [x] Temperature > 10 C
- [x] Analysis requirements absent or unclear

Report Comments

Received Date:	**2012/06/29**	**Time:**	**13:28**	**By:**	**CPR**
Inspected Date:	**2012/06/29**	**Time:**	**16:27**	**By:**	**CPR**
FLAG Created Date:	**2012/06/29**	**Time:**	**16:28**	**By:**	**ABH**

Maxxam Analytics International Corporation o/a Maxxam Analytics 6740 Campobello Road, Mississauga, Ontario, L5N 2L8 Tel: (905) 817-5700 Toll-Free: 800-563-6266 Fax: (905) 817-5777 www.maxxam.ca

Validation Signature Page

Maxxam Job #: B297842

The analytical data and all QC contained in this report were reviewed and validated by the following individual(s).

CHARTERED
Eva Pranjic
CHEMIST

Ewa Pranjic, M.Sc., C.Chem, Scientific Specialist

==

Maxxam has procedures in place to guard against improper use of the electronic signature and have the required "signatories", as per section 5.10.2 of ISO/IEC 17025:2005(E), signing the reports. For Service Group specific validation please refer to the Validation Signature Page.

Your Project #: MB297842
Site Location: PUBLIC LANDS

Attention: SUB CONTRACTOR
MAXXAM ANALYTICS
CAMPOBELLO
6740 CAMPOBELLO ROAD
MISSISSAUGA, ON
CANADA L5N 2L8

Report Date: 2012/07/12

CERTIFICATE OF ANALYSIS

MAXXAM JOB #: B257760
Received: 2012/07/05, 8:40

Sample Matrix: Soil
Samples Received: 28

Analyses	Quantity	Date Extracted	Date Analyzed	Laboratory Method	Analytical Method
Cation Exchange Capacity	28	2012/07/10	2012/07/10	AB SOP-00009	SSMA 18.2, EPA 200.7

* RPDs calculated using raw data. The rounding of final results may result in the apparent difference.

Encryption Key

Please direct all questions regarding this Certificate of Analysis to your Project Manager.

Carmen Mackay, Project Manager Assistant
Email: CMacKay@maxxam.ca
Phone# (403) 291-3077

==

Maxxam has procedures in place to guard against improper use of the electronic signature and have the required "signatories", as per section 5.10.2 of ISO/IEC 17025:2005(E), signing the reports. For Service Group specific validation please refer to the Validation Signature Page.

Total cover pages: 1

Maxxam Job #: B257760
Report Date: 2012/07/12

MAXXAM ANALYTICS
Client Project #: MB297842
Site Location: PUBLIC LANDS

RESULTS OF CHEMICAL ANALYSES OF SOIL

Maxxam ID		DW0199	DW0199	DW0200	DW0201		
Sampling Date		2012/06/21 09:30	2012/06/21 09:30	2012/06/21 09:35	2012/06/21 09:49		
	UNITS	**GG-S1 (NZ2607-01R)**	**GG-S1 (NZ2607-01R) Lab-Dup**	**GG-S2 (NZ2608-01R)**	**GG-D1 (NZ2609-01R)**	**RDL**	**QC Batch**
Elements							
Cation exchange capacity	cmol+/Kg	27	27	17	20	10	5984040

RDL = Reportable Detection Limit

Maxxam ID		DW0202	DW0203	DW0204	DW0205		
Sampling Date		2012/06/21 09:49	2012/06/21 10:05	2012/06/21 10:05	2012/06/21 10:10		
	UNITS	**GG-D2 (NZ2610-01R)**	**LS-S1 (NZ2611-01R)**	**LS-S2 (NZ2612-01R)**	**LS-D1 (NZ2613-01R)**	**RDL**	**QC Batch**
Elements							
Cation exchange capacity	cmol+/Kg	19	13	16	13	10	5984040

RDL = Reportable Detection Limit

Maxxam ID		DW0206	DW0207	DW0208	DW0209		
Sampling Date		2012/06/21 10:10	2012/06/21 11:30	2012/06/21 11:30	2012/06/21 11:35		
	UNITS	**LS-D2 (NZ2614-01R)**	**ED-S1 (NZ2615-01R)**	**ED-S2 (NZ2616-01R)**	**ED-D1 (NZ2617-01R)**	**RDL**	**QC Batch**
Elements							
Cation exchange capacity	cmol+/Kg	13	<10	<10	<10	10	5984040

RDL = Reportable Detection Limit

Maxxam ID		DW0211	DW0212	DW0214	DW0215		
Sampling Date		2012/06/21 11:35	2012/06/21 13:10	2012/06/21 13:10	2012/06/21 13:15		
	UNITS	**ED-D2 (NZ2618-01R)**	**UC-S1 (NZ2619-01R)**	**UC-S2 (NZ2620-01R)**	**UC-D1 (NZ2621-01R)**	**RDL**	**QC Batch**
Elements							
Cation exchange capacity	cmol+/Kg	<10	<10	<10	11	10	5984040

RDL = Reportable Detection Limit

Success Through Science®

Maxxam Job #: B257760
Report Date: 2012/07/12

MAXXAM ANALYTICS
Client Project #: MB297842
Site Location: PUBLIC LANDS

RESULTS OF CHEMICAL ANALYSES OF SOIL

Maxxam ID		DW0216	DW0217	DW0218	DW0219		
Sampling Date		2012/06/21 13:15	2012/06/21 13:45	2012/06/21 13:45	2012/06/21 13:50		
	UNITS	**UC-D2 (NZ2622-01R)**	**PC-S1 (NZ2623-01R)**	**PC-S2 (NZ2624-01R)**	**PC-D1 (NZ2625-01R)**	**RDL**	**QC Batch**
Elements							
Cation exchange capacity	cmol+/Kg	11	12	13	12	10	5984040

RDL = Reportable Detection Limit

Maxxam ID		DW0220		DW0221	DW0222	DW0223		
Sampling Date		2012/06/21 13:50		2012/06/28 09:35	2012/06/28 09:35	2012/06/28 09:45		
	UNITS	**PC-D2 (NZ2626-01R)**	**QC Batch**	**OP-S1 (NZ2627-01R)**	**OP-S2 (NZ2628-01R)**	**OP-D1 (NZ2629-01R)**	**RDL**	**QC Batch**
Elements								
Cation exchange capacity	cmol+/Kg	<10	5984040	21	18	12	10	5984044

RDL = Reportable Detection Limit

Maxxam ID		DW0224	DW0225	DW0226	DW0227		
Sampling Date		2012/06/28 09:45	2012/06/26 13:50	2012/06/26 13:50	2012/06/26 14:00		
	UNITS	**OP-D2 (NZ2630-01R)**	**TC-S1 (NZ2631-01R)**	**TC-S2 (NZ2632-01R)**	**TC-D1 (NZ2633-01R)**	**RDL**	**QC Batch**
Elements							
Cation exchange capacity	cmol+/Kg	12	54	<10	<10	10	5984044

RDL = Reportable Detection Limit

Maxxam ID		DW0228		
Sampling Date		2012/06/26 14:00		
	UNITS	**TC-D2 (NZ2634-01R)**	**RDL**	**QC Batch**
Elements				
Cation exchange capacity	cmol+/Kg	<10	10	5984044

RDL = Reportable Detection Limit

Package 1	5.9°C

Each temperature is the average of up to three cooler temperatures taken at receipt

General Comments

Results relate only to the items tested.

MAXXAM ANALYTICS
Attention: SUB CONTRACTOR
Client Project #: MB297842
P.O. #:
Site Location: PUBLIC LANDS

Quality Assurance Report

Maxxam Job Number: CB257760

QA/QC Batch Num	Init	QC Type	Parameter	Date Analyzed yyyy/mm/dd	Value	Recovery	UNITS	QC Limits
5984040	DL6	RPD [DW0199-01]	Cation exchange capacity	2012/07/10	NC		%	35
5984044	DL6	RPD	Cation exchange capacity	2012/07/10	NC		%	35

Duplicate: Paired analysis of a separate portion of the same sample. Used to evaluate the variance in the measurement.
NC (RPD): The RPD was not calculated. The level of analyte detected in the parent sample and its duplicate was not sufficiently significant to permit a reliable calculation.

Validation Signature Page

Maxxam Job #: B257760

The analytical data and all QC contained in this report were reviewed and validated by the following individual(s).

Lili Zhou, Senior analyst, Inorganic department.

===

Your Project #: ELM SOIL
Site#: MISSISSAUGA
Site Location: SWI
Your C.O.C. #: 43850101, 438501-01-01

Attention: Lana Wilhelm
Credit Valley Conservation
1255 Old Derry Rd
Meadowvale
Mississauga, ON
L5N 6R4

Report Date: 2013/10/09

CERTIFICATE OF ANALYSIS

MAXXAM JOB #: B3G7511
Received: 2013/10/02, 15:00

Sample Matrix: Soil
Samples Received: 6

Analyses	Quantity	Date Extracted	Date Analyzed	Laboratory Method	Method Reference
Chloride (20:1 extract)	6	N/A	2013/10/08	CAM SOP-00463	EPA 325.2
Conductivity	6	N/A	2013/10/08	CAM SOP-00414	APHA 2510
Total Metals Analysis by ICP	1	2013/10/07	2013/10/08	CAM SOP-00408	SW-846 6010C
Total Metals Analysis by ICP	5	2013/10/07	2013/10/09	CAM SOP-00408	SW-846 6010C
Moisture	6	N/A	2013/10/07	CAM SOP-00445	R.Carter,1993
Ammonia-N	6	2013/10/07	2013/10/08	CAM SOP-00441	Carter, SS&A
Nitrate (NO3) and Nitrite (NO2) in Soil	6	N/A	2013/10/08	CAM SOP-00440	SM 4500 NO3I/NO2B
PAH Compounds in Soil by GC/MS (SIM)	6	2013/10/03	2013/10/04	CAM SOP - 00318	EPA 8270
pH CaCl2 EXTRACT	6	2013/10/08	2013/10/08	CAM SOP-00413	SM 4500H+ B
Orthophosphate Analysis	6	N/A	2013/10/08	CAM SOP-00461	Based on EPA 365.1
Total Kjeldahl Nitrogen - Soil	6	2013/10/07	2013/10/08	CAM SOP-00454	EPA 351.2 Rev 2

* RPDs calculated using raw data. The rounding of final results may result in the apparent difference.

Encryption Key

Please direct all questions regarding this Certificate of Analysis to your Project Manager.

Krystal Seedial, Project Manager
Email: KSeedial@maxxam.ca
Phone# (905) 817-5700

==

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Total cover pages: 1

Maxxam Job #: B3G7511
Report Date: 2013/10/09

Credit Valley Conservation
Client Project #: ELM SOIL
Site Location: SWI

RESULTS OF ANALYSES OF SOIL

Maxxam ID		TH8319	TH8320	TH8321	TH8322		
Sampling Date		2013/10/02 13:00	2013/10/02 13:10	2013/10/02 13:40	2013/10/02 13:50		
COC Number		438501-01-01	438501-01-01	438501-01-01	438501-01-01		
	Units	**ED-CELL 6 - SHALLOW**	**ED-CELL 6 - DEEP**	**ED-CELL 4 - SHALLOW**	**ED-CELL 4 - DEEP**	**RDL**	**QC Batch**
Inorganics							
Total Ammonia-N	ug/g	<25	<25	<25	<25	25	3377109
Soluble (20:1) Chloride (Cl)	ug/g	<20	<20	<20	<20	20	3376750
Conductivity	umho/cm	127	115	92	72	1	3377601
Moisture	%	8.2	7.7	9.0	8.8	1.0	3376373
Orthophosphate (P)	ug/g	4.4	2.0	1.5	0.9	0.2	3376806
Available (CaCl2) pH	pH	7.30	7.52	7.49	7.69		3377642
Total Kjeldahl Nitrogen	ug/g	594	415	346	231	10	3376452
Nitrite (N)	ug/g	<0.5	<0.5	<0.5	<0.5	0.5	3376738
Nitrate (N)	ug/g	<2	<2	<2	<2	2	3376738
Nitrate + Nitrite	ug/g	<3	<3	<3	<3	3	3376738

RDL = Reportable Detection Limit
QC Batch = Quality Control Batch

Maxxam Job #: B3G7511
Report Date: 2013/10/09

Credit Valley Conservation
Client Project #: ELM SOIL
Site Location: SWI

RESULTS OF ANALYSES OF SOIL

Maxxam ID		TH8322	TH8323	TH8324	TH8324		
Sampling Date		2013/10/02 13:50	2013/10/02 14:10	2013/10/02 14:20	2013/10/02 14:20		
COC Number		438501-01-01	438501-01-01	438501-01-01	438501-01-01		
	Units	**ED-CELL 4 - DEEP Lab-Dup**	**ED-CELL 1 - SHALLOW**	**ED-CELL 1 - DEEP**	**ED-CELL 1 - DEEP Lab-Dup**	**RDL**	**QC Batch**
Inorganics							
Total Ammonia-N	ug/g	<25	<25	<25		25	3377109
Soluble (20:1) Chloride (Cl)	ug/g		<20	<20		20	3376750
Conductivity	umho/cm		80	85		1	3377601
Moisture	%		8.1	8.5		1.0	3376373
Orthophosphate (P)	ug/g		1.5	1.4	1.5	0.2	3376806
Available (CaCl2) pH	pH	7.69	7.57	7.53			3377642
Total Kjeldahl Nitrogen	ug/g	184	380	351		10	3376452
Nitrite (N)	ug/g		<0.5	<0.5	<0.5	0.5	3376738
Nitrate (N)	ug/g		<2	<2	<2	2	3376738
Nitrate + Nitrite	ug/g		<3	<3	<3	3	3376738

RDL = Reportable Detection Limit
QC Batch = Quality Control Batch

Maxxam Job #: B3G7511
Report Date: 2013/10/09

Credit Valley Conservation
Client Project #: ELM SOIL
Site Location: SWI

ELEMENTS BY ATOMIC SPECTROSCOPY (SOIL)

Maxxam ID		TH8319	TH8319	TH8320	TH8321		
Sampling Date		2013/10/02 13:00	2013/10/02 13:00	2013/10/02 13:10	2013/10/02 13:40		
COC Number		438501-01-01	438501-01-01	438501-01-01	438501-01-01		
	Units	**ED-CELL 6 - SHALLOW**	**ED-CELL 6 - SHALLOW Lab-Dup**	**ED-CELL 6 - DEEP**	**ED-CELL 4 - SHALLOW**	**RDL**	**QC Batch**
Metals							
Acid Extractable Aluminum (Al)	ug/g	2400	2700	1700	1800	50	3376845
Acid Extractable Barium (Ba)	ug/g	21	23	14	17	2.0	3376845
Acid Extractable Beryllium (Be)	ug/g	<0.50	<0.50	<0.50	<0.50	0.50	3376845
Acid Extractable Cadmium (Cd)	ug/g	<0.50	<0.50	<0.50	0.55	0.50	3376845
Acid Extractable Calcium (Ca)	ug/g	85000	91000	92000	96000	500	3376845
Acid Extractable Chromium (Cr)	ug/g	4.6	5.0	2.9	3.3	1.0	3376845
Acid Extractable Cobalt (Co)	ug/g	<2.0	<2.0	<2.0	<2.0	2.0	3376845
Acid Extractable Copper (Cu)	ug/g	11	12	6.7	7.4	2.0	3376845
Acid Extractable Iron (Fe)	ug/g	6600	7200	4400	4600	50	3376845
Acid Extractable Lead (Pb)	ug/g	<5.0	<5.0	6.6	5.6	5.0	3376845
Acid Extractable Magnesium (Mg)	ug/g	7800	8500	8800	10000	50	3376845
Acid Extractable Manganese (Mn)	ug/g	290	330	220	250	1.0	3376845
Acid Extractable Molybdenum (Mo)	ug/g	<2.0	<2.0	<2.0	<2.0	2.0	3376845
Acid Extractable Nickel (Ni)	ug/g	<5.0	<5.0	<5.0	<5.0	5.0	3376845
Acid Extractable Phosphorus (P)	ug/g	420	450	300	280	20	3376845
Acid Extractable Potassium (K)	ug/g	460	480	360	370	200	3376845
Acid Extractable Silver (Ag)	ug/g	<1.0	<1.0	<1.0	<1.0	1.0	3376845
Acid Extractable Sodium (Na)	ug/g	<100	<100	<100	<100	100	3376845
Acid Extractable Strontium (Sr)	ug/g	110	110	110	120	1.0	3376845
Acid Extractable Sulphur (S)	ug/g	200	210	130	160	50	3376845
Acid Extractable Tin (Sn)	ug/g	<20	<20	<20	<20	20	3376845
Acid Extractable Vanadium (V)	ug/g	9.6	11	6.6	7.1	5.0	3376845
Acid Extractable Zinc (Zn)	ug/g	20	22	15	15	5.0	3376845

RDL = Reportable Detection Limit
QC Batch = Quality Control Batch

ELEMENTS BY ATOMIC SPECTROSCOPY (SOIL)

Maxxam ID		TH8322	TH8323	TH8324		
Sampling Date		2013/10/02 13:50	2013/10/02 14:10	2013/10/02 14:20		
COC Number		438501-01-01	438501-01-01	438501-01-01		
	Units	**ED-CELL 4 - DEEP**	**ED-CELL 1 - SHALLOW**	**ED-CELL 1 - DEEP**	**RDL**	**QC Batch**
Metals						
Acid Extractable Aluminum (Al)	ug/g	1800	1800	1800	50	3376845
Acid Extractable Barium (Ba)	ug/g	14	14	13	2.0	3376845
Acid Extractable Beryllium (Be)	ug/g	<0.50	<0.50	<0.50	0.50	3376845
Acid Extractable Cadmium (Cd)	ug/g	0.82	<0.50	<0.50	0.50	3376845
Acid Extractable Calcium (Ca)	ug/g	120000	95000	97000	500	3376845
Acid Extractable Chromium (Cr)	ug/g	4.7	3.2	2.9	1.0	3376845
Acid Extractable Cobalt (Co)	ug/g	<2.0	<2.0	<2.0	2.0	3376845
Acid Extractable Copper (Cu)	ug/g	7.4	6.8	8.6	2.0	3376845
Acid Extractable Iron (Fe)	ug/g	5100	4700	4600	50	3376845
Acid Extractable Lead (Pb)	ug/g	9.7	<5.0	5.8	5.0	3376845
Acid Extractable Magnesium (Mg)	ug/g	33000	6900	13000	50	3376845
Acid Extractable Manganese (Mn)	ug/g	270	230	220	1.0	3376845
Acid Extractable Molybdenum (Mo)	ug/g	<2.0	<2.0	<2.0	2.0	3376845
Acid Extractable Nickel (Ni)	ug/g	<5.0	<5.0	<5.0	5.0	3376845
Acid Extractable Phosphorus (P)	ug/g	360	300	300	20	3376845
Acid Extractable Potassium (K)	ug/g	350	330	300	200	3376845
Acid Extractable Silver (Ag)	ug/g	<1.0	<1.0	<1.0	1.0	3376845
Acid Extractable Sodium (Na)	ug/g	110	<100	<100	100	3376845
Acid Extractable Strontium (Sr)	ug/g	100	120	120	1.0	3376845
Acid Extractable Sulphur (S)	ug/g	180	120	120	50	3376845
Acid Extractable Tin (Sn)	ug/g	<20	<20	<20	20	3376845
Acid Extractable Vanadium (V)	ug/g	8.7	7.3	7.3	5.0	3376845
Acid Extractable Zinc (Zn)	ug/g	39	12	16	5.0	3376845

RDL = Reportable Detection Limit
QC Batch = Quality Control Batch

Maxxam Job #: B3G7511
Report Date: 2013/10/09

Credit Valley Conservation
Client Project #: ELM SOIL
Site Location: SWI

SEMI-VOLATILE ORGANICS BY GC-MS (SOIL)

Maxxam ID		TH8319	TH8320	TH8321	TH8322		
Sampling Date		2013/10/02 13:00	2013/10/02 13:10	2013/10/02 13:40	2013/10/02 13:50		
COC Number		438501-01-01	438501-01-01	438501-01-01	438501-01-01		
	Units	**ED-CELL 6 - SHALLOW**	**ED-CELL 6 - DEEP**	**ED-CELL 4 - SHALLOW**	**ED-CELL 4 - DEEP**	**RDL**	**QC Batch**
Polyaromatic Hydrocarbons							
Acenaphthene	ug/g	<0.0050	<0.0050	<0.0050	<0.0050	0.0050	3373772
Acenaphthylene	ug/g	<0.0050	<0.0050	<0.0050	<0.0050	0.0050	3373772
Anthracene	ug/g	<0.0050	<0.0050	<0.0050	<0.0050	0.0050	3373772
Benzo(a)anthracene	ug/g	<0.0050	<0.0050	<0.0050	<0.0050	0.0050	3373772
Benzo(a)pyrene	ug/g	<0.0050	0.0083	0.0078	<0.0050	0.0050	3373772
Benzo(b/j)fluoranthene	ug/g	0.0098	0.016	0.018	<0.0050	0.0050	3373772
Benzo(g,h,i)perylene	ug/g	0.0067	0.0088	0.0097	<0.0050	0.0050	3373772
Benzo(k)fluoranthene	ug/g	<0.0050	<0.0050	<0.0050	<0.0050	0.0050	3373772
Chrysene	ug/g	<0.0050	0.0060	0.0068	<0.0050	0.0050	3373772
Dibenz(a,h)anthracene	ug/g	<0.0050	<0.0050	<0.0050	<0.0050	0.0050	3373772
Fluoranthene	ug/g	<0.0050	0.0070	0.0078	<0.0050	0.0050	3373772
Fluorene	ug/g	<0.0050	<0.0050	<0.0050	<0.0050	0.0050	3373772
Indeno(1,2,3-cd)pyrene	ug/g	0.0057	0.0079	0.0087	<0.0050	0.0050	3373772
1-Methylnaphthalene	ug/g	<0.0050	<0.0050	<0.0050	<0.0050	0.0050	3373772
2-Methylnaphthalene	ug/g	<0.0050	<0.0050	<0.0050	<0.0050	0.0050	3373772
Naphthalene	ug/g	<0.0050	<0.0050	<0.0050	<0.0050	0.0050	3373772
Phenanthrene	ug/g	<0.0050	<0.0050	<0.0050	<0.0050	0.0050	3373772
Pyrene	ug/g	<0.0050	0.0070	0.0063	<0.0050	0.0050	3373772
Surrogate Recovery (%)							
D10-Anthracene	%	85	84	90	92		3373772
D14-Terphenyl (FS)	%	82	80	83	80		3373772
D8-Acenaphthylene	%	76	73	77	73		3373772

RDL = Reportable Detection Limit
QC Batch = Quality Control Batch

Maxxam Job #: B3G7511
Report Date: 2013/10/09

Credit Valley Conservation
Client Project #: ELM SOIL
Site Location: SWI

SEMI-VOLATILE ORGANICS BY GC-MS (SOIL)

Maxxam ID		TH8323	TH8324		
Sampling Date		2013/10/02 14:10	2013/10/02 14:20		
COC Number		438501-01-01	438501-01-01		
	Units	**ED-CELL 1 - SHALLOW**	**ED-CELL 1 - DEEP**	**RDL**	**QC Batch**
Polyaromatic Hydrocarbons					
Acenaphthene	ug/g	<0.0050	<0.0050	0.0050	3373772
Acenaphthylene	ug/g	<0.0050	<0.0050	0.0050	3373772
Anthracene	ug/g	<0.0050	<0.0050	0.0050	3373772
Benzo(a)anthracene	ug/g	0.0056	0.0050	0.0050	3373772
Benzo(a)pyrene	ug/g	0.010	0.0085	0.0050	3373772
Benzo(b/j)fluoranthene	ug/g	0.020	0.017	0.0050	3373772
Benzo(g,h,i)perylene	ug/g	0.011	0.0085	0.0050	3373772
Benzo(k)fluoranthene	ug/g	0.0056	0.0050	0.0050	3373772
Chrysene	ug/g	0.0081	0.0075	0.0050	3373772
Dibenz(a,h)anthracene	ug/g	<0.0050	<0.0050	0.0050	3373772
Fluoranthene	ug/g	0.0071	0.010	0.0050	3373772
Fluorene	ug/g	<0.0050	<0.0050	0.0050	3373772
Indeno(1,2,3-cd)pyrene	ug/g	0.010	0.0075	0.0050	3373772
1-Methylnaphthalene	ug/g	<0.0050	<0.0050	0.0050	3373772
2-Methylnaphthalene	ug/g	<0.0050	<0.0050	0.0050	3373772
Naphthalene	ug/g	<0.0050	<0.0050	0.0050	3373772
Phenanthrene	ug/g	<0.0050	<0.0050	0.0050	3373772
Pyrene	ug/g	0.0066	0.0095	0.0050	3373772
Surrogate Recovery (%)					
D10-Anthracene	%	89	83		3373772
D14-Terphenyl (FS)	%	82	79		3373772
D8-Acenaphthylene	%	76	72		3373772

RDL = Reportable Detection Limit
QC Batch = Quality Control Batch

Maxxam Analytics International Corporation o/a Maxxam Analytics 6740 Campobello Road, Mississauga, Ontario, L5N 2L8 Tel: (905) 817-5700 Toll-Free: 800-563-6266 Fax: (905) 817-5777 www.maxxam.ca

Package 1	18.0°C

Each temperature is the average of up to three cooler temperatures taken at receipt

GENERAL COMMENTS

Results relate only to the items tested.

Credit Valley Conservation
Attention: Lana Wilhelm
Client Project #: ELM SOIL
P.O. #:
Site Location: SWI

Quality Assurance Report

Maxxam Job Number: MB3G7511

QA/QC Batch Num Init	QC Type	Parameter	Date Analyzed yyyy/mm/dd	Value	Recovery	Units	QC Limits
3373772 DTI	Matrix Spike	D10-Anthracene	2013/10/04		85	%	50 - 130
		D14-Terphenyl (FS)	2013/10/04		82	%	50 - 130
		D8-Acenaphthylene	2013/10/04		81	%	50 - 130
		Acenaphthene	2013/10/04		96	%	50 - 130
		Acenaphthylene	2013/10/04		95	%	50 - 130
		Anthracene	2013/10/04		98	%	50 - 130
		Benzo(a)anthracene	2013/10/04		109	%	50 - 130
		Benzo(a)pyrene	2013/10/04		111	%	50 - 130
		Benzo(b/j)fluoranthene	2013/10/04		103	%	50 - 130
		Benzo(g,h,i)perylene	2013/10/04		87	%	50 - 130
		Benzo(k)fluoranthene	2013/10/04		114	%	50 - 130
		Chrysene	2013/10/04		102	%	50 - 130
		Dibenz(a,h)anthracene	2013/10/04		87	%	50 - 130
		Fluoranthene	2013/10/04		102	%	50 - 130
		Fluorene	2013/10/04		95	%	50 - 130
		Indeno(1,2,3-cd)pyrene	2013/10/04		92	%	50 - 130
		1-Methylnaphthalene	2013/10/04		92	%	50 - 130
		2-Methylnaphthalene	2013/10/04		88	%	50 - 130
		Naphthalene	2013/10/04		91	%	50 - 130
		Phenanthrene	2013/10/04		95	%	50 - 130
		Pyrene	2013/10/04		103	%	50 - 130
	Spiked Blank	D10-Anthracene	2013/10/04		83	%	50 - 130
		D14-Terphenyl (FS)	2013/10/04		79	%	50 - 130
		D8-Acenaphthylene	2013/10/04		79	%	50 - 130
		Acenaphthene	2013/10/04		92	%	50 - 130
		Acenaphthylene	2013/10/04		93	%	50 - 130
		Anthracene	2013/10/04		95	%	50 - 130
		Benzo(a)anthracene	2013/10/04		104	%	50 - 130
		Benzo(a)pyrene	2013/10/04		107	%	50 - 130
		Benzo(b/j)fluoranthene	2013/10/04		108	%	50 - 130
		Benzo(g,h,i)perylene	2013/10/04		84	%	50 - 130
		Benzo(k)fluoranthene	2013/10/04		104	%	50 - 130
		Chrysene	2013/10/04		98	%	50 - 130
		Dibenz(a,h)anthracene	2013/10/04		81	%	50 - 130
		Fluoranthene	2013/10/04		97	%	50 - 130
		Fluorene	2013/10/04		95	%	50 - 130
		Indeno(1,2,3-cd)pyrene	2013/10/04		88	%	50 - 130
		1-Methylnaphthalene	2013/10/04		88	%	50 - 130
		2-Methylnaphthalene	2013/10/04		85	%	50 - 130
		Naphthalene	2013/10/04		88	%	50 - 130
		Phenanthrene	2013/10/04		92	%	50 - 130
		Pyrene	2013/10/04		98	%	50 - 130
	Method Blank	D10-Anthracene	2013/10/04		101	%	50 - 130
		D14-Terphenyl (FS)	2013/10/04		82	%	50 - 130
		D8-Acenaphthylene	2013/10/04		74	%	50 - 130
		Acenaphthene	2013/10/04	<0.0050		ug/g	
		Acenaphthylene	2013/10/04	<0.0050		ug/g	
		Anthracene	2013/10/04	<0.0050		ug/g	
		Benzo(a)anthracene	2013/10/04	<0.0050		ug/g	
		Benzo(a)pyrene	2013/10/04	<0.0050		ug/g	
		Benzo(b/j)fluoranthene	2013/10/04	<0.0050		ug/g	
		Benzo(g,h,i)perylene	2013/10/04	<0.0050		ug/g	
		Benzo(k)fluoranthene	2013/10/04	<0.0050		ug/g	
		Chrysene	2013/10/04	<0.0050		ug/g	
		Dibenz(a,h)anthracene	2013/10/04	<0.0050		ug/g	

Credit Valley Conservation
Attention: Lana Wilhelm
Client Project #: ELM SOIL
P.O. #:
Site Location: SWI

Quality Assurance Report (Continued)

Maxxam Job Number: MB3G7511

QA/QC Batch Num Init	QC Type	Parameter	Date Analyzed yyyy/mm/dd	Value	Recovery	Units	QC Limits
3373772 DTI	Method Blank	Fluoranthene	2013/10/04	<0.0050		ug/g	
		Fluorene	2013/10/04	<0.0050		ug/g	
		Indeno(1,2,3-cd)pyrene	2013/10/04	<0.0050		ug/g	
		1-Methylnaphthalene	2013/10/04	<0.0050		ug/g	
		2-Methylnaphthalene	2013/10/04	<0.0050		ug/g	
		Naphthalene	2013/10/04	<0.0050		ug/g	
		Phenanthrene	2013/10/04	<0.0050		ug/g	
		Pyrene	2013/10/04	<0.0050		ug/g	
	RPD	Acenaphthene	2013/10/04	NC		%	40
		Acenaphthylene	2013/10/04	NC		%	40
		Anthracene	2013/10/04	NC		%	40
		Fluoranthene	2013/10/04	NC		%	40
		Fluorene	2013/10/04	NC		%	40
		1-Methylnaphthalene	2013/10/04	NC		%	40
		2-Methylnaphthalene	2013/10/04	NC		%	40
		Naphthalene	2013/10/04	NC		%	40
		Phenanthrene	2013/10/04	NC		%	40
3376373 JV1	RPD	Moisture	2013/10/07	0		%	20
3376452 C_N	Matrix Spike [TH8322-01]	Total Kjeldahl Nitrogen	2013/10/08		82	%	80 - 120
	QC Standard	Total Kjeldahl Nitrogen	2013/10/08		98	%	80 - 120
	Spiked Blank	Total Kjeldahl Nitrogen	2013/10/08		107	%	80 - 120
	Method Blank	Total Kjeldahl Nitrogen	2013/10/08	<10		ug/g	
	RPD [TH8322-01]	Total Kjeldahl Nitrogen	2013/10/08	22.7		%	40
3376738 SS4	Matrix Spike [TH8324-01]	Nitrite (N)	2013/10/08		104	%	75 - 125
		Nitrate (N)	2013/10/08		100	%	75 - 125
		Nitrate + Nitrite	2013/10/08		101	%	75 - 125
	Spiked Blank	Nitrite (N)	2013/10/08		100	%	75 - 125
		Nitrate (N)	2013/10/08		97	%	75 - 125
		Nitrate + Nitrite	2013/10/08		97	%	75 - 125
	Method Blank	Nitrite (N)	2013/10/08	<0.5		ug/g	
		Nitrate (N)	2013/10/08	<2		ug/g	
		Nitrate + Nitrite	2013/10/08	<3		ug/g	
	RPD [TH8324-01]	Nitrite (N)	2013/10/08	NC		%	25
		Nitrate (N)	2013/10/08	NC		%	25
		Nitrate + Nitrite	2013/10/08	NC		%	25
3376750 ADB	Matrix Spike	Soluble (20:1) Chloride (Cl)	2013/10/08		113	%	75 - 125
	Spiked Blank	Soluble (20:1) Chloride (Cl)	2013/10/08		98	%	75 - 125
	Method Blank	Soluble (20:1) Chloride (Cl)	2013/10/08	<20		ug/g	
	RPD	Soluble (20:1) Chloride (Cl)	2013/10/08	NC		%	35
3376806 ADB	Matrix Spike [TH8324-01]	Orthophosphate (P)	2013/10/08		118	%	75 - 125
	Spiked Blank	Orthophosphate (P)	2013/10/08		108	%	75 - 125
	Method Blank	Orthophosphate (P)	2013/10/08	<0.2		ug/g	
	RPD [TH8324-01]	Orthophosphate (P)	2013/10/08	2.2		%	35
3376845 SUK	Matrix Spike [TH8319-01]	Acid Extractable Aluminum (Al)	2013/10/08		NC	%	75 - 125
		Acid Extractable Barium (Ba)	2013/10/08		96	%	75 - 125
		Acid Extractable Beryllium (Be)	2013/10/08		103	%	75 - 125
		Acid Extractable Cadmium (Cd)	2013/10/08		103	%	75 - 125
		Acid Extractable Calcium (Ca)	2013/10/08		NC	%	75 - 125
		Acid Extractable Chromium (Cr)	2013/10/08		98	%	75 - 125
		Acid Extractable Cobalt (Co)	2013/10/08		100	%	75 - 125
		Acid Extractable Copper (Cu)	2013/10/08		101	%	75 - 125

Credit Valley Conservation
Attention: Lana Wilhelm
Client Project #: ELM SOIL
P.O. #:
Site Location: SWI

Quality Assurance Report (Continued)

Maxxam Job Number: MB3G7511

QA/QC Batch Num Init	QC Type	Parameter	Date Analyzed yyyy/mm/dd	Value	Recovery	Units	QC Limits
3376845 SUK	Matrix Spike						
	[TH8319-01]	Acid Extractable Iron (Fe)	2013/10/08		82	%	75 - 125
		Acid Extractable Lead (Pb)	2013/10/08		100	%	75 - 125
		Acid Extractable Magnesium (Mg)	2013/10/08		106	%	75 - 125
		Acid Extractable Manganese (Mn)	2013/10/08		101	%	75 - 125
		Acid Extractable Molybdenum (Mo)	2013/10/08		98	%	75 - 125
		Acid Extractable Nickel (Ni)	2013/10/08		99	%	75 - 125
		Acid Extractable Phosphorus (P)	2013/10/08		NC	%	75 - 125
		Acid Extractable Potassium (K)	2013/10/08		101	%	75 - 125
		Acid Extractable Silver (Ag)	2013/10/08		102	%	75 - 125
		Acid Extractable Sodium (Na)	2013/10/08		107	%	75 - 125
		Acid Extractable Strontium (Sr)	2013/10/08		103	%	75 - 125
		Acid Extractable Sulphur (S)	2013/10/08		110	%	75 - 125
		Acid Extractable Tin (Sn)	2013/10/08		99	%	75 - 125
		Acid Extractable Vanadium (V)	2013/10/08		98	%	75 - 125
		Acid Extractable Zinc (Zn)	2013/10/08		103	%	75 - 125
	Spiked Blank	Acid Extractable Aluminum (Al)	2013/10/08		102	%	80 - 120
		Acid Extractable Barium (Ba)	2013/10/08		100	%	80 - 120
		Acid Extractable Beryllium (Be)	2013/10/08		103	%	80 - 120
		Acid Extractable Cadmium (Cd)	2013/10/08		102	%	80 - 120
		Acid Extractable Calcium (Ca)	2013/10/08		104	%	80 - 120
		Acid Extractable Chromium (Cr)	2013/10/08		103	%	80 - 120
		Acid Extractable Cobalt (Co)	2013/10/08		105	%	80 - 120
		Acid Extractable Copper (Cu)	2013/10/08		102	%	80 - 120
		Acid Extractable Iron (Fe)	2013/10/08		104	%	80 - 120
		Acid Extractable Lead (Pb)	2013/10/08		108	%	80 - 120
		Acid Extractable Magnesium (Mg)	2013/10/08		100	%	80 - 120
		Acid Extractable Manganese (Mn)	2013/10/08		102	%	80 - 120
		Acid Extractable Molybdenum (Mo)	2013/10/08		101	%	80 - 120
		Acid Extractable Nickel (Ni)	2013/10/08		107	%	80 - 120
		Acid Extractable Phosphorus (P)	2013/10/08		108	%	80 - 120
		Acid Extractable Potassium (K)	2013/10/08		98	%	80 - 120
		Acid Extractable Silver (Ag)	2013/10/08		101	%	80 - 120
		Acid Extractable Sodium (Na)	2013/10/08		103	%	80 - 120
		Acid Extractable Strontium (Sr)	2013/10/08		100	%	80 - 120
		Acid Extractable Sulphur (S)	2013/10/08		102	%	80 - 120
		Acid Extractable Tin (Sn)	2013/10/08		104	%	80 - 120
		Acid Extractable Vanadium (V)	2013/10/08		100	%	80 - 120
		Acid Extractable Zinc (Zn)	2013/10/08		103	%	80 - 120
	Method Blank	Acid Extractable Aluminum (Al)	2013/10/08	<50		ug/g	
		Acid Extractable Barium (Ba)	2013/10/08	<2.0		ug/g	
		Acid Extractable Beryllium (Be)	2013/10/08	<0.50		ug/g	
		Acid Extractable Cadmium (Cd)	2013/10/08	<0.50		ug/g	
		Acid Extractable Calcium (Ca)	2013/10/08	<50		ug/g	
		Acid Extractable Chromium (Cr)	2013/10/08	<1.0		ug/g	
		Acid Extractable Cobalt (Co)	2013/10/08	<2.0		ug/g	
		Acid Extractable Copper (Cu)	2013/10/08	<2.0		ug/g	
		Acid Extractable Iron (Fe)	2013/10/08	<50		ug/g	
		Acid Extractable Lead (Pb)	2013/10/08	<5.0		ug/g	
		Acid Extractable Magnesium (Mg)	2013/10/08	<50		ug/g	
		Acid Extractable Manganese (Mn)	2013/10/08	<1.0		ug/g	
		Acid Extractable Molybdenum (Mo)	2013/10/08	<2.0		ug/g	
		Acid Extractable Nickel (Ni)	2013/10/08	<5.0		ug/g	
		Acid Extractable Phosphorus (P)	2013/10/08	<20		ug/g	
		Acid Extractable Potassium (K)	2013/10/08	<200		ug/g	

Maxxam Analytics International Corporation o/a Maxxam Analytics 6740 Campobello Road, Mississauga, Ontario, L5N 2L8 Tel: (905) 817-5700 Toll-Free: 800-563-6266 Fax: (905) 817-5777 www.maxxam.ca

Credit Valley Conservation
Attention: Lana Wilhelm
Client Project #: ELM SOIL
P.O. #:
Site Location: SWI

Quality Assurance Report (Continued)

Maxxam Job Number: MB3G7511

QA/QC Batch Num Init	QC Type	Parameter	Date Analyzed yyyy/mm/dd	Value	Recovery	Units	QC Limits
3376845 SUK	Method Blank	Acid Extractable Silver (Ag)	2013/10/08	<1.0		ug/g	
		Acid Extractable Sodium (Na)	2013/10/08	<100		ug/g	
		Acid Extractable Strontium (Sr)	2013/10/08	<1.0		ug/g	
		Acid Extractable Sulphur (S)	2013/10/08	<50		ug/g	
		Acid Extractable Tin (Sn)	2013/10/08	<20		ug/g	
		Acid Extractable Vanadium (V)	2013/10/08	<5.0		ug/g	
		Acid Extractable Zinc (Zn)	2013/10/08	<5.0		ug/g	
	RPD [TH8319-01]	Acid Extractable Aluminum (Al)	2013/10/08	9.8		%	30
		Acid Extractable Barium (Ba)	2013/10/08	7.3		%	30
		Acid Extractable Beryllium (Be)	2013/10/08	NC		%	30
		Acid Extractable Cadmium (Cd)	2013/10/08	NC		%	30
		Acid Extractable Calcium (Ca)	2013/10/08	6.5		%	30
		Acid Extractable Chromium (Cr)	2013/10/08	NC		%	30
		Acid Extractable Cobalt (Co)	2013/10/08	NC		%	30
		Acid Extractable Copper (Cu)	2013/10/08	12.7		%	30
		Acid Extractable Iron (Fe)	2013/10/08	8.9		%	30
		Acid Extractable Lead (Pb)	2013/10/08	NC		%	30
		Acid Extractable Magnesium (Mg)	2013/10/08	9.0		%	30
		Acid Extractable Manganese (Mn)	2013/10/08	12.1		%	30
		Acid Extractable Molybdenum (Mo)	2013/10/08	NC		%	30
		Acid Extractable Nickel (Ni)	2013/10/08	NC		%	30
		Acid Extractable Phosphorus (P)	2013/10/08	7.9		%	30
		Acid Extractable Potassium (K)	2013/10/08	NC		%	30
		Acid Extractable Silver (Ag)	2013/10/08	NC		%	30
		Acid Extractable Sodium (Na)	2013/10/08	NC		%	30
		Acid Extractable Strontium (Sr)	2013/10/08	5.1		%	30
		Acid Extractable Sulphur (S)	2013/10/08	NC		%	30
		Acid Extractable Tin (Sn)	2013/10/08	NC		%	30
		Acid Extractable Vanadium (V)	2013/10/08	NC		%	30
		Acid Extractable Zinc (Zn)	2013/10/08	NC		%	30
3377109 COP	Matrix Spike [TH8322-01]	Total Ammonia-N	2013/10/08		NC	%	75 - 125
	Spiked Blank	Total Ammonia-N	2013/10/08		110	%	80 - 120
	Method Blank	Total Ammonia-N	2013/10/08	<25		ug/g	
	RPD [TH8322-01]	Total Ammonia-N	2013/10/08	NC		%	35
3377601 L_A	QC Standard	Conductivity	2013/10/08		115	%	N/A
	Spiked Blank	Conductivity	2013/10/08		100	%	90 - 110
	Method Blank	Conductivity	2013/10/08	1, RDL=1		umho/cm	
	RPD	Conductivity	2013/10/08	1.5		%	10

Duplicate: Paired analysis of a separate portion of the same sample. Used to evaluate the variance in the measurement.
Matrix Spike: A sample to which a known amount of the analyte of interest has been added. Used to evaluate sample matrix interference.
QC Standard: A sample of known concentration prepared by an external agency under stringent conditions. Used as an independent check of method accuracy.
Spiked Blank: A blank matrix sample to which a known amount of the analyte, usually from a second source, has been added. Used to evaluate method accuracy.
Method Blank: A blank matrix containing all reagents used in the analytical procedure. Used to identify laboratory contamination.
Surrogate: A pure or isotopically labeled compound whose behavior mirrors the analytes of interest. Used to evaluate extraction efficiency.
NC (Matrix Spike): The recovery in the matrix spike was not calculated. The relative difference between the concentration in the parent sample and the spiked amount was not sufficiently significant to permit a reliable recovery calculation.
NC (RPD): The RPD was not calculated. The level of analyte detected in the parent sample and its duplicate was not sufficiently significant to permit a reliable calculation.

Fundamental Laboratory Acceptance Guideline

Invoice To:
Credit Valley Conservation
ATTN: Phil James
1255 Old Derry Rd
Meadowvale
Mississauga, ON
L5N 6R4
Client Contact:
Lana Wilhelm

Maxxam Job #:	B3G7511
Date Received:	2013/10/02
Your C.O.C. #:	43850101
Your Project #:	ELM SOIL
Maxxam Project Manager:	Krystal Seedial
Quote #:	B30269
Site #:	MISSISSAUGA

No discrepancies noted.

Report Comments

Received Date:	**2013/10/02**	**Time:**	**15:00**	**By:**	
Inspected Date:		**Time:**		**By:**	
FLAG Created Date:		**Time:**	**00:00**	**By:**	

Validation Signature Page

Maxxam Job #: B3G7511

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ELM DRIVE, CITY OF MISSISSAUGA

LOW IMPACT DEVELOPMENT INFRASTRUCTURE PERFORMANCE AND RISK MANAGEMENT ASSESSMENT

Appendix G

Thermal Mitigation Analysis and Methodology

NOTICE

1 ELM DRIVE LID THERMAL MITIGATION ANALYSIS

Impervious surfaces such as parking lots, roads and rooftops represent a large portion of land cover in urbanized areas. The materials used in building these areas have a very high thermal capacity and readily absorb solar radiation. When precipitation events occur on warm sunny days, the stormwater flows along these surfaces and absorbs the heat stored within the impervious surface through conduction. This stormwater becomes warmer and in most cases flows into the nearest stormwater sewer system where it flows into the local stream and river catchments.

The bioretention cells at Elm Drive are being evaluated for thermal mitigation potential by developing event mean temperatures and thermal loads of inflows and outflows. In order to assess thermal mitigation and calculate event mean temperatures, HOBO pendent temperature loggers were deployed at the inflow catchbasin and at the outflow manhole. Both loggers are set to record temperatures at ten minute intervals and are downloaded every two weeks.

2 METHODOLOGY

The catchment runoff flowing into the LID practices was not measured directly, however, calculated using the runoff method suggested in the Elm Drive Monitoring Report[1] and by Schueler[2]. Outflows were monitored using an ISCO 4150 logger and level probe with a compound weir.

2.1 Calculation Steps

The following steps were taken to estimate thermal mitigation and EMTs. Sample calculations are presented in **Table 1**.

Step 1: Inflow Estimate

The flow entering the LID treatment train (Q_{in}) was estimated using Equation (1) suggested in the Elm Drive Monitoring Report[3].

$$Q_{in} = A * P * Rv * ConversionFactor \quad (1)$$

Where:

A is the Total catchment area (m^2) = ---- m^2

P is Precipitation (mm)

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[1] Credit Valley Conservation Watershed Protection and Restoration Team, Wright Water Engineers, Inc, Geosyntec Consultants. 2013. Elm Drive City of Mississauga, Low Impact Development Infrastructure Performance and Risk Assessment. Interim Technical Report 2011-2013

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

[3] CVC et. al., 2013

Rv is Runoff Coefficient (unitless) = ----

Conversion Factor is 1.0

Finally,

$Q_{in} = 2908.65 * P$

Table 1 provides precipitation data in column 2 and the results of the inflow estimation in column 4.

Step 2: Inflow Event Mean Temperature (EMT_{in}) Calculation

Inflow EMT is the event mean temperature of the runoff entering treatment train. The EMT was calculated using equation (2)[4, 5]:

$$EMT_{in} = \frac{\sum T_{in} Q_{in} dt}{\sum Q_{in} dt} \quad (2)$$

Where:

Q_{in} is the measured stormwater flow rate

T_{in} is water temperature

dt is the time duration of the event.

Column 5 of **Table 1** shows the calculations of numerator of equation (2) which is then summed for one event and then divided by total flow estimated for that event (EMT row of **Table 1**)

Step 3: Inflow Thermal Loading (TL_{in}) Calculations

The TL_{in} is calculated using equation (3)[6]:

$$TL_{in} = Q_{in} * p * T_{in} * C * t \quad (3)$$

Where:

Q_{in} is the flow rate in (m^3/s)

p is the density of water (assumed constant at 1000 kg/m^3)

T_{in} is inflow water temperature (ºC)

[4] Sabouri, F & Gharabagi, B & Mahboubu, A.A, McBean, E.A. 2013. Impervious surfaces and sewer pipe effects on stormwater runoff temperature. Journal of Hydrology, 2013. 502: 10-17

[5] Natarajan, P & Davis, A.P. 2010. Thermal Reduction by an Underground Storm-Water Detention System. Journal of Environmental Engineering, 2010.136:520-526.

[6] Winston, R.J. & Hunt, W.F. & Lord, W.G. 2011. Thermal Mitigation of Urban Storm Water by Level Spreader-Vegetative Filter Strips. Journal of Environmental Engineering, 2011.137:707-716

C is the heat capacity of water (assumed constant at 4186 J/kg/ºC)

t is time(s)

The TL_{in} calculations are shown in column 6 for **Table 1** and an example is given below

Example: Thermal Load Inflows

- Unit conversion from litres to m^3: 581.73/1000 (column 4)
- Multiply by constants 4186 J/kg/ºC and 1000 kg/m³, EMT_{in} = 22.52°C, and divide by 10^6 to convert Joules to Mega Joules (Column 6)
- Sum the product in column 6 for total inflow TL_{in}.

Step 4: Outflow Estimates

The out flows are collected at the bioretention outlet. A level sensor and a compound weir is used to measure flows. The flows are then corrected for drainage area (the drainage area of the site is larger than that draining into the catch basins on the northern side of the LID practices) using an area proportion factor. The contributing area on the north side of the LID is approximately 75% of the total catchment. Therefore the area factor is 0.75.

Step 6: Outflow Event Mean Temperature EMTout Calculation

The outlet is the event mean temperature leaving the treatment train. The EMT was calculated using equation (2) (Sabouri et al., 2013; Natatajan et al., 2012):

Where:

Q_{out} is the measured stormwater flow rate

T_{out} is water temperature

dt is the time duration of the event.

Column 9 shows the calculation of numerator of equation 2 which is then summed for one event and then divided by total out flow estimated for that event (EMT row of **Table 1**).

Step 7: Outflow Thermal Loading TLout Calculation

The TL_{out} is calculated using equation (3)[7]:

Where:

Q_{out} is the outflow rate in (m³/s)

p is the density of water (assumed constant at 1000 kg/m³)

[7] Winston et. al., 2011

T_{out} is outflow water temperature (ºC)

C is the heat capacity of water (assumed constant at 4186 J/kg/ºC)

t is time(s)

The TL_{out} calculations are shown in column 10 for **Table 1** and an example is given below

Example: Thermal Load Outlet

- Unit Conversions from liters to m³: 0.518 l/s/1000 for m^3 (column 8)
- 0.000518*catchment factor of 0.75
- Multiply by constants 4186 J/kg/ºC and 1000 kg/m³, EMT_{out} = 18.31°C, and divide by 10^6 to convert Joules to Mega Joules (Column 6)
- Sum the product in column 10 for total outflow TL_{out}.

Step 8: Thermal Mitigation

To calculate the total thermal mitigation from inflow to outflow of the LID, column 6 and column 10 are totalled and subtracted. The thermal mitigation is given in the TL reduction row of **Table 1**.

Table 1: EMT and Thermal Loading Calculation Summary for July 27th, 2013 Event

Date/Time	Inflow Precipitation (mm)	Inflow Temp T_{in}	Col 2 x 2908.65	Col 4 x Col 3	Thermal Load TL_{in} (MJ)	Outlet Temp T_{out} °C	Outflow (l/s) Qout	Col 7x8	Thermal Load TL_{out} (MJ)
1	2	3	4	5	6	7	8	9	10
2013-07-27 13:00	0.2	22.525	581.73	13103.46825	54.83	18.521	0	0	0
2013-07-27 13:10	0	22.525	0	0	0.00	18.521	0	0	0
2013-07-27 13:20	0	22.525	0	0	0.00	18.521	0	0	0
2013-07-27 13:30	0	22.525	0	0	0.00	18.521	0	0	0
2013-07-27 13:40	0	22.525	0	0	0.00	18.521	0	0	0
2013-07-27 13:50	0	22.525	0	0	0.00	18.521	0	0	0
2013-07-27 14:00	0.2	22.525	581.73	13103.46825	54.83	18.521	0	0	0
2013-07-27 14:10	0	22.525	0	0	0.00	18.521	0	0	0
2013-07-27 14:20	0	22.525	0	0	0.00	18.521	0	0	0
2013-07-27 14:30	0	22.525	0	0	0.00	18.521	0	0	0
2013-07-27 14:40	0	22.525	0	0	0.00	18.616	0	0	0

2013-07-27 14:50	0	22.525	0	0	0.00	18.616	0	0	0
2013-07-27 15:00	0.8	22.621	2326.92	52637.25732	219.32	18.616	0	0	0
2013-07-27 15:10	0.2	22.525	581.73	13103.46825	54.83	18.616	0	0	0
2013-07-27 15:20	13	22.621	37812.45	855355.4315	3563.94	18.616	0	0	0
2013-07-27 15:30	3.2	21.664	9307.68	201641.5795	877.28	18.901	0	0	0
2013-07-27 15:40	0.4	25.708	1163.46	29910.22968	109.66	19.282	0	0	0
2013-07-27 15:50	0	27.173	0	0	0.00	18.901	0	0	0
2013-07-27 16:00	0	27.665	0	0	0.00	18.711	0	0	0
2013-07-27 16:10	0	27.665	0	0	0.00	18.521	0.518	9.593878	17.86
2013-07-27 16:20	0	27.567	0	0	0.00	18.426	0.567	10.447542	19.55
2013-07-27 16:30	0	27.468	0	0	0.00	18.236	0.518	9.446248	17.86
2013-07-27 16:40	0	27.272	0	0	0.00	18.236	0.38	6.92968	13.10
2013-07-27 16:50	0	27.173	0	0	0.00	18.14	0.257	4.66198	8.86
2013-07-27 17:00	0	27.075	0	0	0.00	18.14	0.185	3.3559	6.38
2013-07-27	0	27.075	0	0	0.00	18.14	0.12	2.1768	4.14

17:10										
2013-07-27 17:20	0	26.977	0	0	0.00	18.14	0.091	1.65074	3.14	
2013-07-27-17:30	0	26.879	0	0	0.00	18.14	0.023	0.41722	0.79	
Total			**52355.7**	**1178854.903**	**4934.69**		**2.659**	**48.679988**	**91.70**	
EMT	**22.52 In**					**18.31 Out**				
TL Reduction Total Col 6-Total Col 10	**4842.99 MJ**									

3 RESULTS AND DISCUSSION

This section discusses the thermal analysis from the 2013 study period. The Elm Drive retrofit was able to retain all flow from the catchment for 12 out of 25 events during the 2013 study period. This accounts for 48% of all events during the warmest months of the year.

Table 2 is a summary of all 25 precipitation events which occurred during the 2013 study period within the Elm Drive catchment area. Events generating outflows (13) are labelled with check marks. All other events are labelled with X symbol. More than 60% of all events during the study period fell within the 0-20 mm event range.

Table 2: May to September 2013 Event Precipitation Summary

Beginning of Precipitation	Total Precipitation mm	0-10 mm	10-20 mm	20-30 mm	>30 mm
		10	**6**	**4**	**5**
2013-05-10 08:40	24			√	
2013-05-28 16:10	25			√	
2013-05-31 17:10	2.8	X			
2013-06-01 14:00	10.2		X		
2013-06-06 13:20	8	X			
2013-06-10 06:20	36				√
2013-06-13 7:20	9	X			
2013-06-16 05:00	14.8		√		
2013-06-22 11:50	2.2	X			
2013-06-25 6:10	6.2	X			
2013-06-28 11:00	15.4		√		
2013-07-05 06:10	60.2				√
2013-07-07 0:30	5.2	X			
2013-07-07 15:30	9.6	√			
2013-07-08 16:30	105				√
2013-07-19 17:00	6.6	X			
2013-07-27 13:00	19		√		
2013-07-31 15:50	31.6				√
2013-08-02 16:20	10.6		X		
2013-08-26 5:50	15.6		X		
2013-08-27 17:30	24.4			√	
2013-09-07 07:50	20.4			√	
2013-09-11 15:30	9.6	X			
2013-09-20 22:10	42				√

2013-09-30 3:00	2.4	X			

Figure 1 and **Figure 2** show the percent EMT and TL reduction for four precipitation event ranges. All 25 precipitation events between May and September are included. Ten events fell in the catchment area within the 0 to 10 mm range with only one generating flow. Due to the high rate of flow retention in the 0 to 10 mm range, the median and maximum reduction for both EMT and TL is 100%. In the 10 to 20 mm range the thermal load reduction rate is more than 90% and three out of the six events within the range did not generate flow.

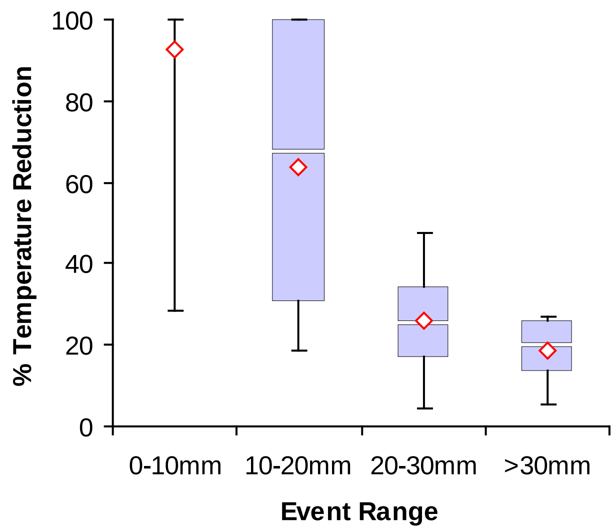

Figure 1: Event Mean Temperature Reduction

Table 3: Summary of Temperature Reduction Data in Figure 1

	0-10mm	**10-20mm**	**20-30mm**	**>30mm**
Count	**10**	**6**	**4**	**5**
Min	28.67	18.69	4.56	5.63
25th	100	31.12001	16.95436	13.97008
Median	100.00	67.53	25.57	20.23
75th	100	100	34.37404	26.00131
Max	100.00	100.00	47.31	26.82
Mean	92.87	63.93	25.76	18.53
SD	22.55653	39.86793	17.83511	8.869489

Due to climate change the potential for more rain events falling within the greater than 30 mm range is increasing. Of the 5 events falling within this range, 3 events fell into a greater than 40 mm range with one event over 100 mm. The study shows a 68% mean reduction in thermal load and a 72% median reduction for events within this range. Excluding all events greater than 30 mm the data shows the LID will reduce thermal loads by over 80%.

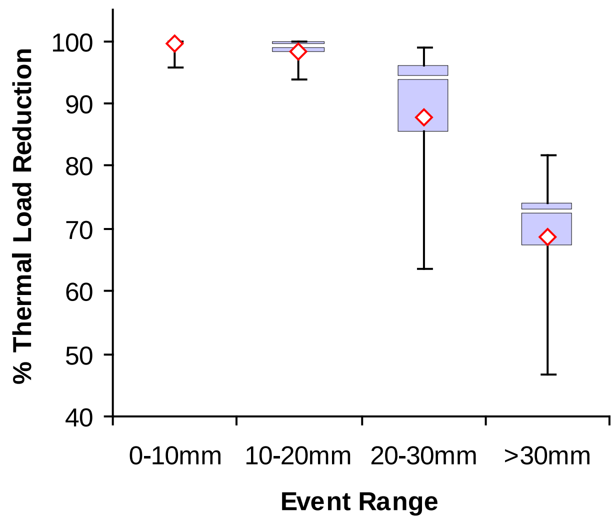

Figure 2: Thermal Load Reduction

Table 4: Summary of Thermal Load Reduction Data in Figure 2

	0-10 mm	10-20 mm	20-30 mm	>30 mm
Count	**10**	**6**	**4**	**5**
Min	95.80	93.79	63.71	46.80
25th	100	98.23743	85.63496	67.2741
Median	100.00	99.26	94.11	72.90
75th	100	100	96.20001	74.17125
Max	100.00	100.00	98.98	81.76
Mean	99.58	98.41	87.73	68.58
SD	1.328157	2.408729	16.20363	13.22546

EMT for the 13 events from May to September where outflows were generated is presented in **Figure 3**. All events within this timeframe had a higher mean temperature at the inlet monitoring location than at the outlet location. However, given the seasonal variation in the data shown in **Figure 4** the median from the inlet and outlet EMT gives a better representation of the temperature change. Additionally, all events had higher TL introduced into the LID at the inlet than the loads leaving the system at the outlet. **Figure 4** gives an overview of all TL data for events generating flow. The data shows the median TL value from the inflows to be significantly higher than the median load value of the outflows.

Data	EMT Outlet	EMT Inlet
Count	**13**	**13**
Min	8.86	16.18
25th	14.45428	19.62643
Median	18.25	22.52
75th	18.79633	24.17705
Max	20.89	25.58
Mean	16.53	21.56
SD	3.57354	3.145728

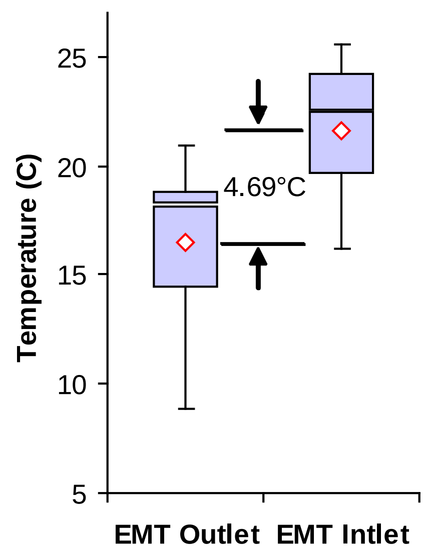

Figure 3: Inlet and Outlet Event Mean Temperatures for 2013 Outflow Events

Data	TL Outlet Totals	TL Inlet Totals
Count	**13**	**13**
Min	49.96	2990.46
25th	125.4815	4874.861
Median	347.45	4934.69
75th	2745.55	9066.433
Max	16517.75	31050.67
Mean	2482.77	8731.51
SD	4489.114	7780.511

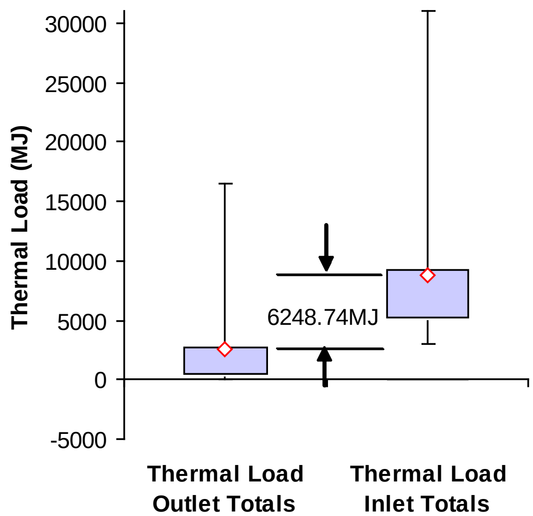

Figure 4: Thermal Load Totals for 2013 Outflow Events

TL reduction is presented further in both **Figure 5 and 6** on an event basis where an average of 83.08% TL reduction is observed over the monitored timeline. Due to seasonal temperature variation and the amount of precipitation during any given event the thermal load reduction fluctuates throughout the year. The data shows a minimum of 60% reduction in TL for 12 out of the 13 events. The only event not consistent with this trend occurred on July 8th 2013. In one hour 96.4 mm of rain fell within the Elm Drive catchment and the treatment train produced a 46.8% thermal load reduction.

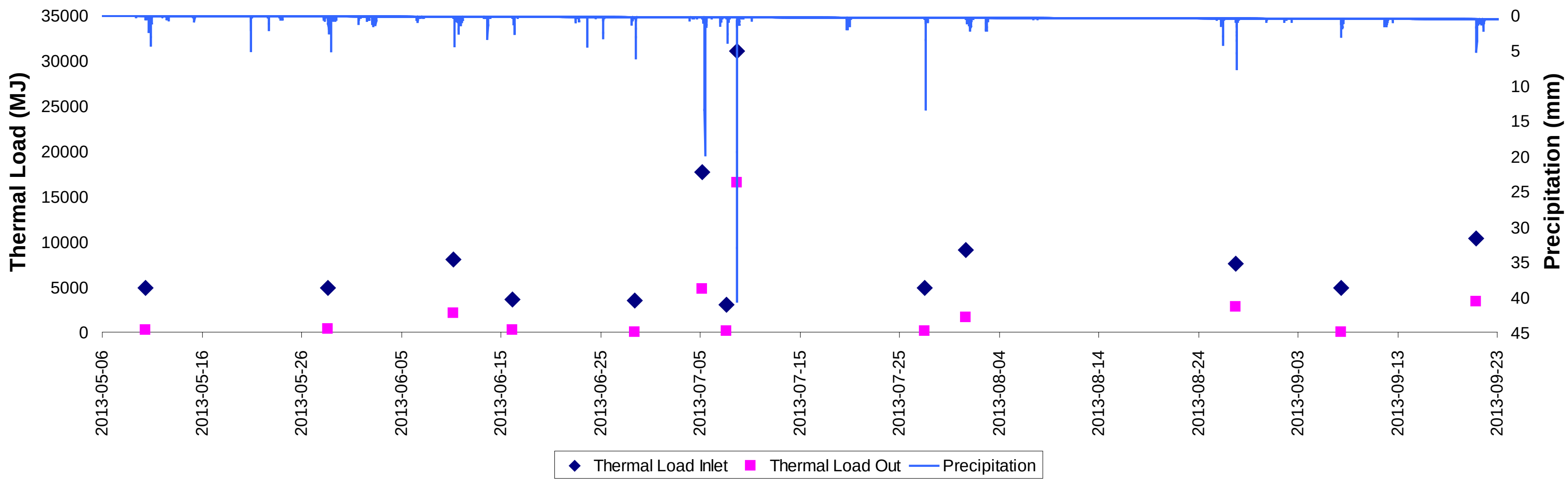

Figure 5: Thermal Load Reductions from Inlet to Outlet

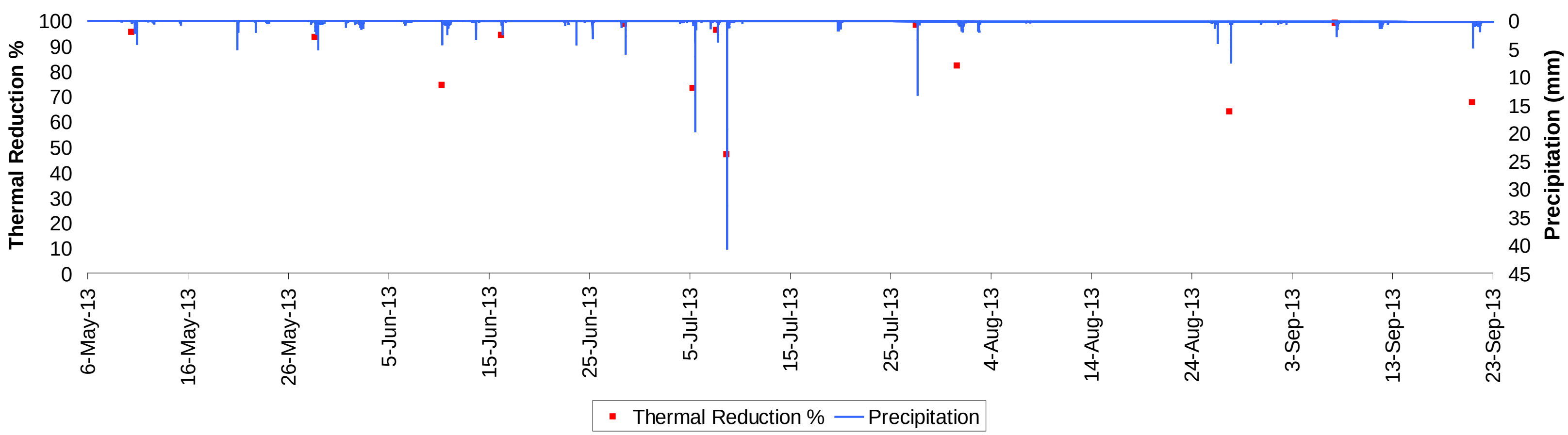

Figure 6: Thermal Load Reductions for all 2013 Events with Outflows

Table 5 is a summary of all the EMT and total TL data collected from May to September. Included is the duration each event occurred. In the summer months the average air temperature is lower than the inlet EMT, indicating the ground surface is warmer than the air. Additionally there is little variation between the EMTs of events which occur in the evening when the ground surface has been warmed through the day and events occurring in the morning and afternoon.

Table 5: Summary of 2013 Elm Drive LID Flow Events

Beginning of Precipitation	End of Precipitation	Duration	Average Air Temp (C)	Inlet		Outlet		% EMT Reduction	% TL Reduction
				EMT	Thermal Load Totals (MJ)	EMT	Thermal Load Totals (MJ)		
2013/05/10 08:40	2013/05/11 04:20	20hr event approx	12.14	16.82	4914.18	8.86	232.20	47.31	95.27
2013/05/28 16:10	2013/05/29 12:40	20hr event approx	15.61	16.18	4924.39	11.31	347.45	30.06	92.94
2013/06/10 06:20	2013/06/11 03:20	21hr event	16.41	18.29	8017.11	13.38	2070.72	26.82	74.17
2013/06/16 05:00	2013/06/16 14:40	Morn/Afternoon	20.25	20.59	3660.40	14.45	227.30	29.80	93.79
2013/06/28 11:00	2013/06/28 14:20	Afternoon	19.93	23.79	3534.28	15.45	52.15	35.07	98.52
2013/07/05 06:10	2013/07/05 15:40	Morn/Afternoon	22.03	24.18	17662.22	17.89	4786.82	26.00	72.90
2013/07/07 15:30	2013/07/07 23:00	Evening	22.69	25.58	2990.46	18.25	125.48	28.67	95.80
2013/07/08 16:30	2013/07/09 08:30	Evening/Nighttime	20.51	24.29	31050.67	20.89	16517.75	13.97	46.80
2013/07/27 13:00	2013/07/27 15:40	Afternoon	20.25	22.52	4934.69	18.31	91.70	18.69	98.14
2013/07/31 15:50	2013/08/01 10:10	Evening	19.11	23.56	9066.43	18.80	1653.28	20.23	81.76
2013/08/27 17:30	2013/08/28 00:40	Evening	21.62	24.66	7564.95	19.46	2745.55	21.09	63.71
2013/09/07 07:50	2013/09/07 14:10	Morn/Afternoon	16.47	19.63	4874.86	18.73	49.96	4.56	98.98
2013/09/20 22:10	2013/09/21 17:30	19hr event approx	15.14	20.17	10315.03	19.04	3375.69	5.63	67.27

Although the EMT and TL are consistently reduced from inflow to outflow throughout the study period, a significant reduction in EMT and TL is observed during the summer months where the potential for thermal pollution into fresh water catchments is greater.

As mentioned previously the precipitation event where the least amount of thermal mitigation was achieved occurred on July 8th 2013. During this event 74.4 mm of rain fell between 16:30 and 17:00 generating outflows 20 minutes after rain began. The total amount of rainfall for July 8th was measured at 104.2 mm. Event flows along with precipitation and inflow and outflow temperature for this event are presented in **Figure 7**. Given the magnitude of the event significant reductions in TL through the LID was achieved (**Figure 8**).

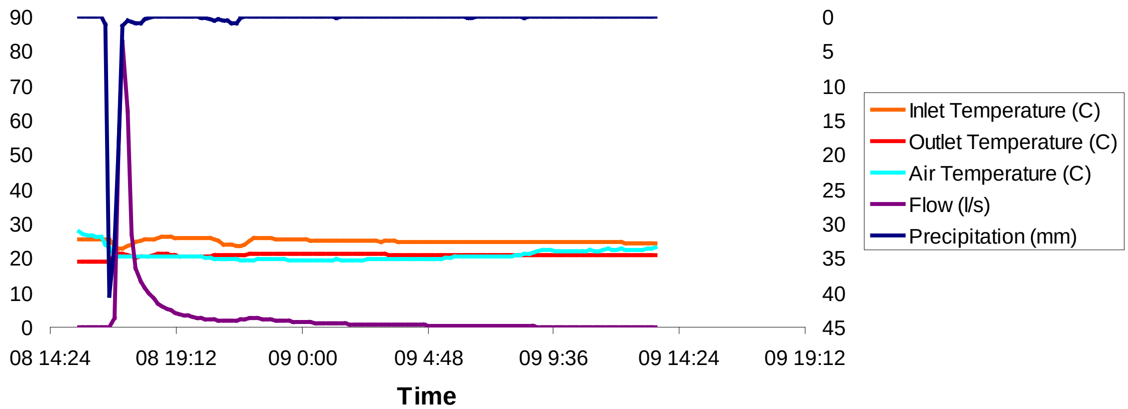

Figure 7: Inflows and Outflows with Temperature during July 8th Event

Table 6: Summary of July 8th 2013 Temperature Data

Temperature Collected	*Inlet*	*Outlet*	*Air*
Maximum ºC	26.20	21.28	27.69
Minimum ºC	22.72	19.00	19.29
Mean ºC	24.91	20.87	20.88

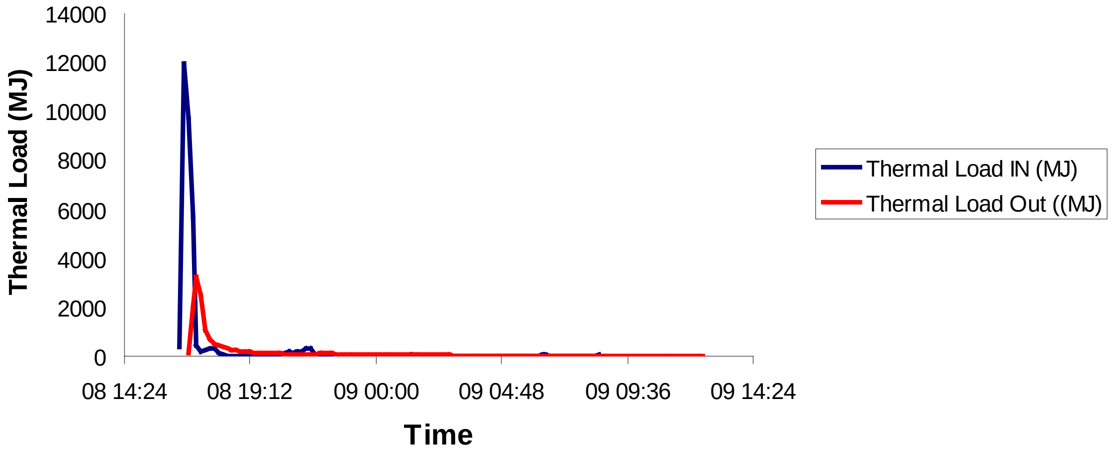

Figure 8: Thermal loads during July 8th 2013 Event

ELM DRIVE, CITY OF MISSISSAUGA

LOW IMPACT DEVELOPMENT INFRASTRUCTURE PERFORMANCE AND RISK MANAGEMENT ASSESSMENT

Appendix H
Intensification of Urban Water Cycle

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** 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).

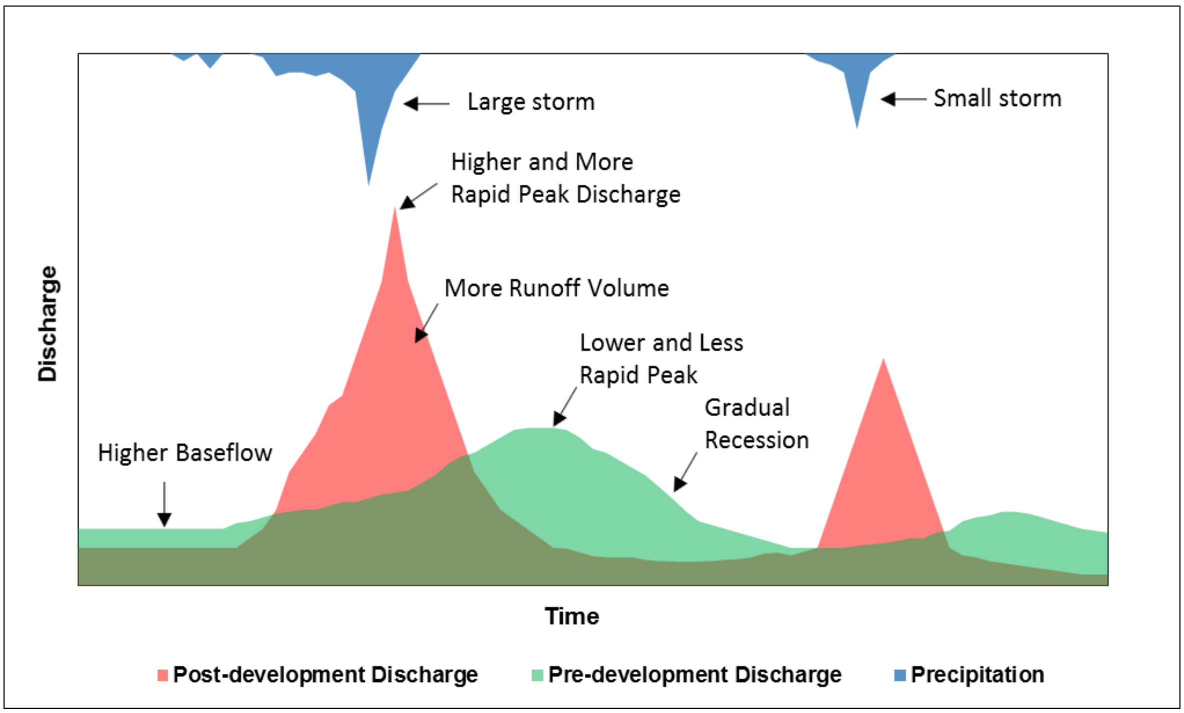

Figure 1: Changes in stream flow hydrograph as a result of urbanization (adapted from Schueler, 1987)

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[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 2a).**

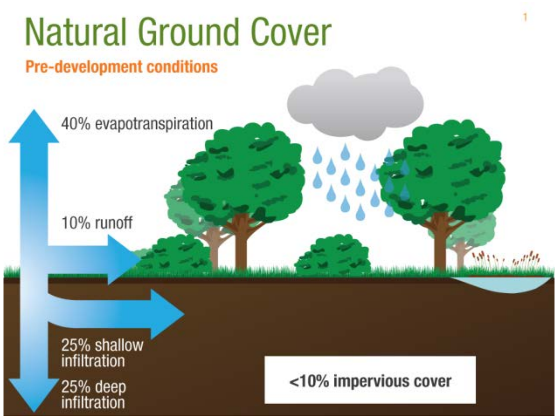

Figure 2a: Hydrologic Cycle: Natural ground cover Predevelopment Conditions

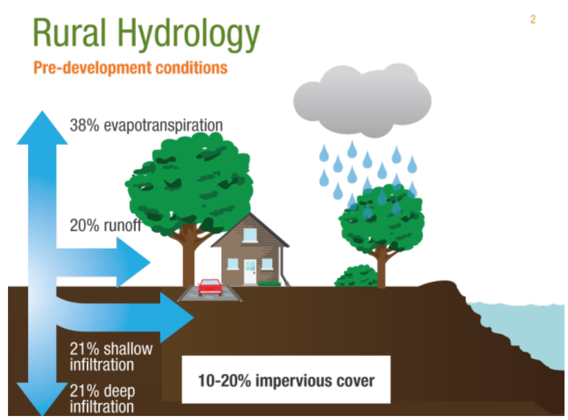

Figure 2b: Hydrologic Cycle: 10-20% Impervious - cover - Predevelopment Conditions

(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 3a)**. 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.

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[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 3a**). Current stormwater management has taken an "end of pipe" approach, using gutters and piping systems to carry rainwater into ponds or detention basins **(Figure 3b)**. 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.

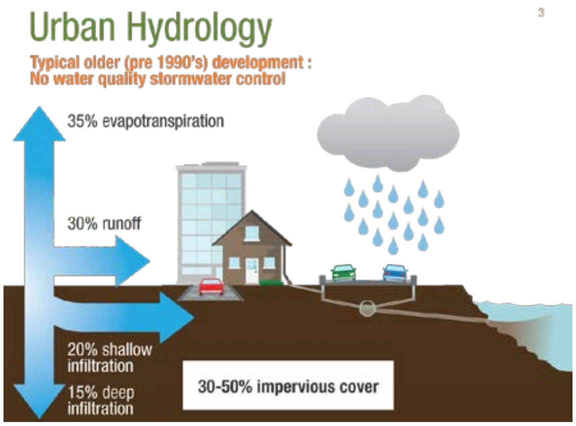

Figure 3a: Stormwater Management with no water quality control

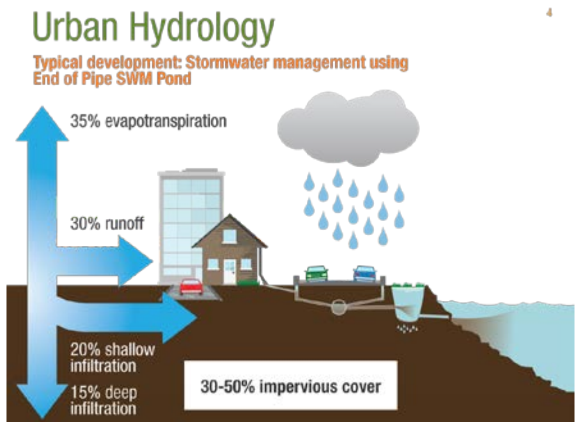

Figure 3b: Stormwater management using SWM ponds.

(Adapted from FIRSWG, 1998)

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 4**).

Figure 4: 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 5**). Although most effective when implemented on a community-wide basis, using LID practices on a smaller scale can also have a positive impact.

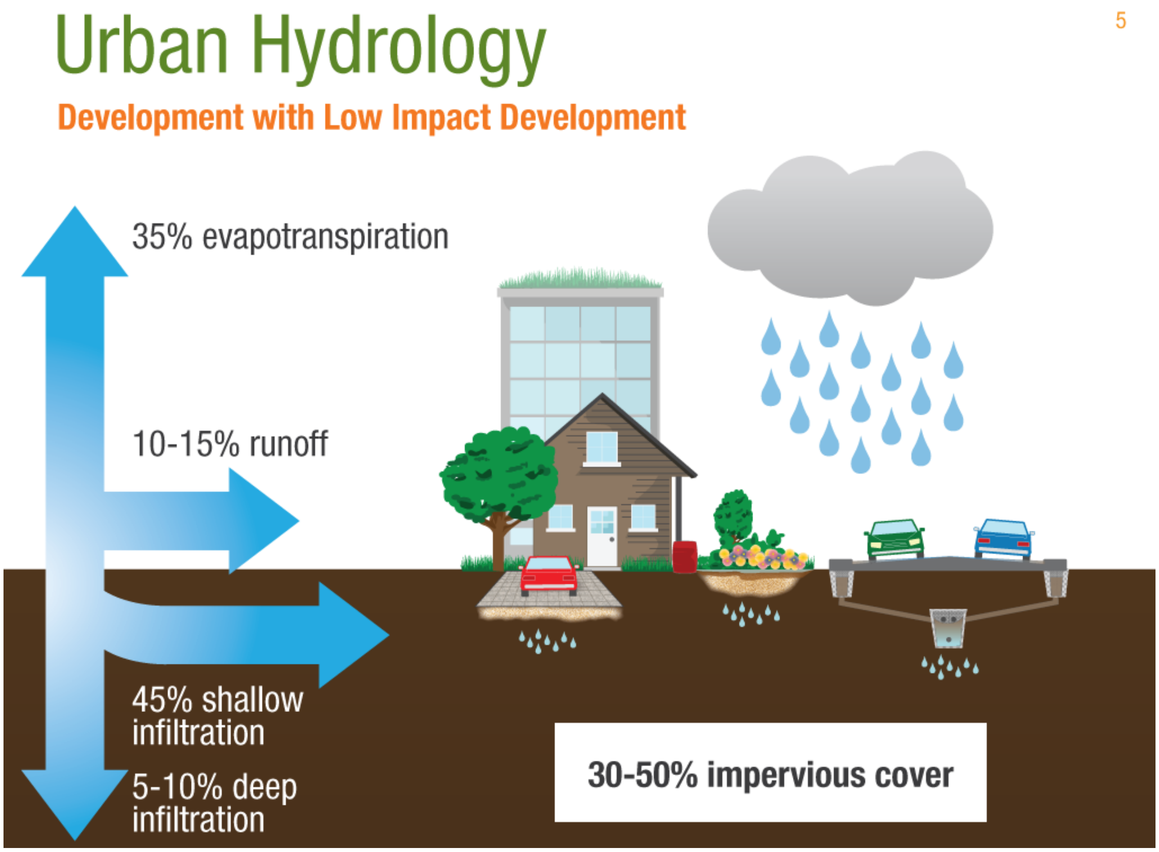

Figure 5: Urban water cycle with Low Impact Development stormwater Management - (Adapted from FIRSWG, 1998)

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].

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 6**).

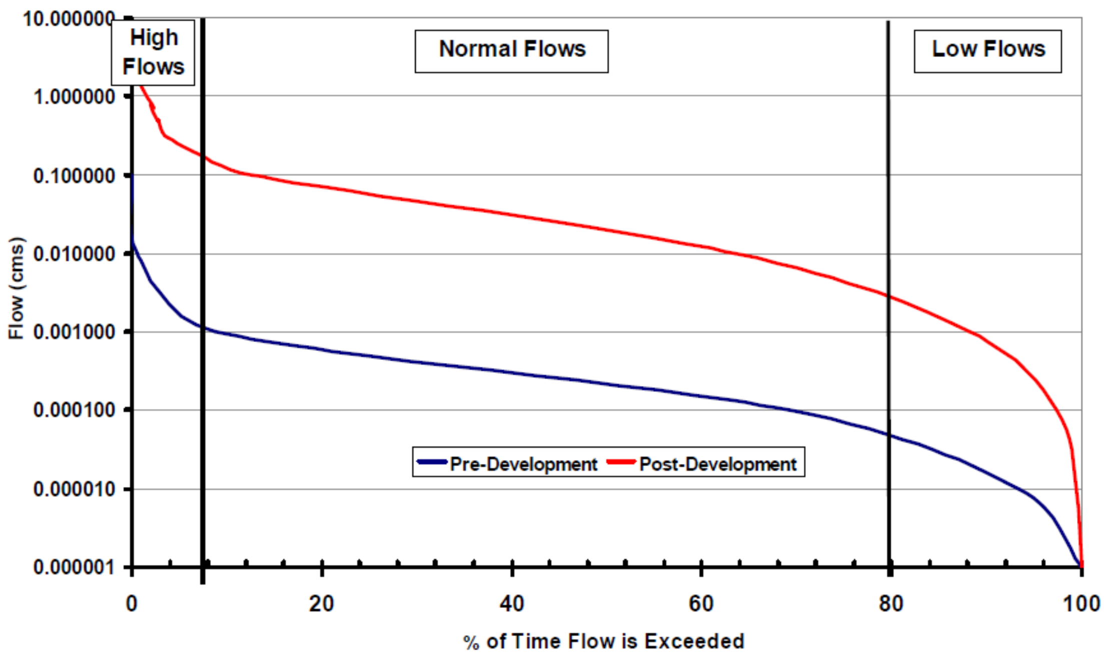

Figure 6: Increasing trends in stream flow pre- and post-construction in Fletchers' Creek

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 7**).

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.

Figure 7: High stream flow in Fletcher's Creek

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.

In fact, LID sites can prevent runoff for events up to 25 mm in depth (**Figure 8**). 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.

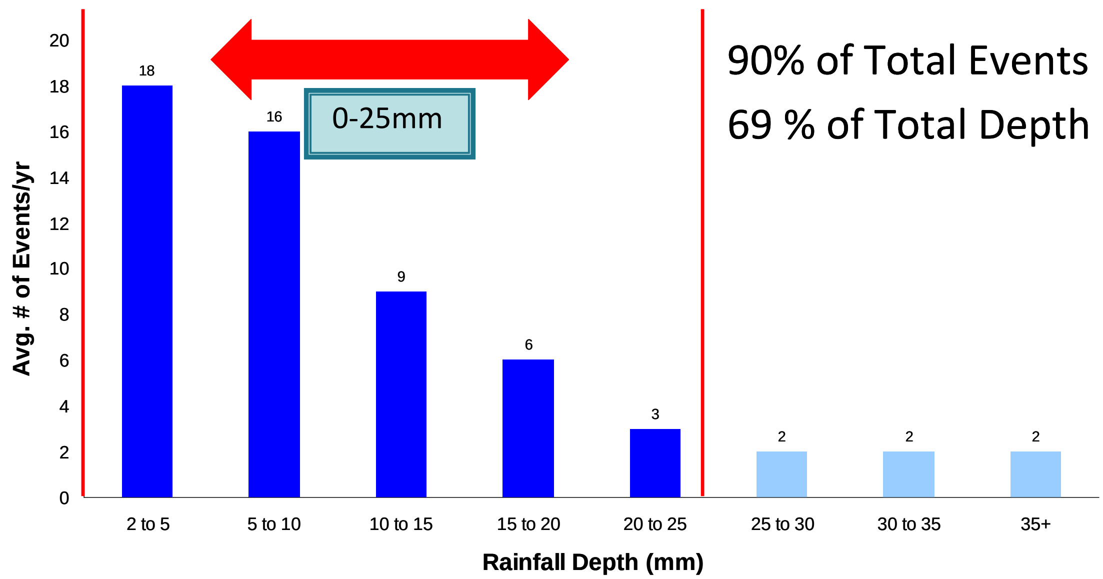

Figure 8: Typical Annual Rainfall Frequency Distribution for Toronto Lester B. Pearson 1960-2012

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

Figure 9: Sediment Plume from Credit River to Lake Ontario (Photo Credit: Aquafor Beech, 1990)

and have resulted in up to $87 million a year in lost revenue to local economies[8].

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 10**. 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.

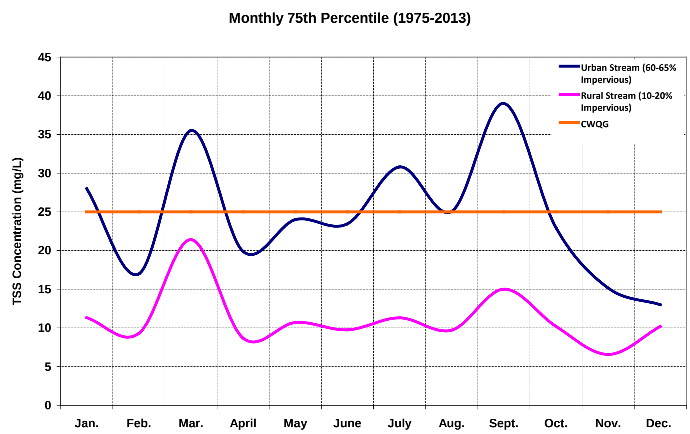

Figure 10: Monthly 75th Percentile Total Suspended Solids concentration compared at an urban vs. rural catchment

Note: Different urban/rural stream 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 11**). This is due to the greater level of impervious surfaces and lack of stormwater volume control in the urban stream. Elevated concentrations

[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

of nutrients in the summer season is the major factor contributing to excess algae growth and depressed dissolved oxygen in receiving streams[9].

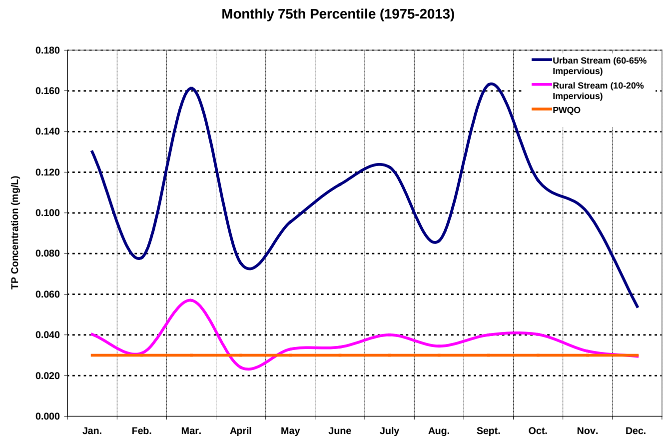

Figure 11: Monthly 75th Percentile Total Phosphorus concentration compared at an urban vs. rural catchment

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.

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 recognize 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.

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.

Figure 12: High TSS from urban runoff in Springbrook Creek habitat of Redside Dace

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[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/

[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*.